VULNERABILITY AND ADAPTATION TO CLIMATE CHANGE IN SUSTAINABLE FOREST MANAGEMENT AND THE FOREST INDUSTRY IN SASKATCHEWAN

A Thesis Submitted to the College of

Graduate and Postdoctoral Studies

in Partial Fulfillment of the Requirements

for the Degree of Doctor of Philosophy

in the School of Environment and Sustainability

University of Saskatchewan

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ABSTRACT

As the climate continues to change, forest ecosystems are experiencing stresses that have not been seen in the past. These changes are impacting many facets of the boreal forests around the world. In Canada, the Canadian Council of Forest Ministers (CCFM) has recommended that it is essential to consider both climate change and future climatic variability in all aspects of sustainable forest management (SFM). Forest policy and management practices need to evolve in the face of a changing climate in order to be sustainable.

In Saskatchewan, Canada, the Ministry of Environment has recognized that climate change adaptation in forest policy and management practices is required. In December 2014, stakeholders from the Saskatchewan forest industry and government came together to explore potential future climate scenarios, impacts on operations and management, and how to address adaptation for SFM in the future. Using this workshop as a starting point, this thesis examines, in more detail, some of these concerns and the gaps between policy and forest management in relation to climate change. One of the main goals of this research includes the application of the CCFM approach in a case study at the Forest Management Area (FMA) scale, to identify, develop, and mainstream tools for adaptation. Through the course of this research, the results have demonstrated that the CCFM approach can be successfully applied at the FMA level and have aided Mistik Management Ltd. (Mistik) in identifying vulnerabilities in their SFM with respect to climate change. Mistik has also developed and begun mainstreaming adaptation options to address climate change into both strategic and operational aspects of their SFM. The results from the Mistik case study are also being used by the provincial government to aid in guiding future policy adaptation and development. This will put policy makers and forest

managers in a better position to assess and manage SFM vulnerabilities and mainstream adaptation options into planning and management of Saskatchewan's forests.

The Saskatchewan provincial government and Mistik Management Ltd. (a forestry company in Saskatchewan, Canada) partnered to undertake a vulnerability assessment in order to analyze climate change and sustainable forest management. Mistik is currently developing a 20-year forest management plan and this vulnerability assessment will be incorporated into their plan. The vulnerability assessment of their management area was completed using a practitioner's guidebook developed through the CCFM. Through this assessment, climate change impacts were identified, and Mistik's adaptive capacity was analyzed. Based on the vulnerability assessment and the analysis of their adaptive capacity, Mistik has now begun mainstreaming the results into their forest management plan and their SFM system. Saskatchewan Environment Forest Service Branch is also using the results of the Mistik vulnerability assessment to help guide forest policy direction to increase responsiveness and flexibility and promote adaptation in management in an environment of increasing climatic uncertainty in Saskatchewan.

All three steps of this undertaking focussed on climate change at the FMA scale, and was seen as daunting to both the government and the forest managers involved. The structured decision-making approach of the CCFM framework allowed the company and government representatives to follow the logical steps from a vulnerability assessment, to mainstreaming climate change adaptations, to seeing how adaptation in the industry needed to be supported by changes to the policy and governance framework of the province. In this regard, this dissertation takes a major step forward in helping to illustrate that a process that was originally seen by all parties as a formidable task, is in fact both feasible, and quite valuable.

ACKNOWLEDGMENTS

I would like to thank my Ph.D. supervisor, Dr. Colin Laroque for his support and advice throughout this project and the completion of this thesis, as well as the members of my Ph.D. advisory committee: Dr. Mark Johnston, Dr. Rory McIntosh, Dr. Jeremy Rayner, and Dr. Ken Van Rees.

I would like to thank Jason Edwards and Tim Williamson at Canadian Forest Services in Edmonton, for all of their guidance, support and encouragement throughout this project, as well as Dave Peterson at the US Forest Service. I would also like to recognize Roger Nesdoly (Mistik Management Ltd. General Manager) and Kevin Gillis (Mistik Management Ltd. Certification Coordinator) for their support and hard work though out this project. It would not have been a success without them.

DEDICATION

I would like to dedicate my thesis to my husband, Brent, without whom I would not have made it this far. His patience, understanding and unfailing love and support helped me keep going when I wanted to quit. He is my rock and helps keep me balanced.

I would also like to say a special thanks to my mentor, Mark who has helped guide and encourage me throughout this process and has taught me a great deal.

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LIST OF ABBREVIATIONS

CCFM	Canadian Council of Forest Ministers
C & I	Criteria and Indicators
CSA	Canadian Standards Association
EMS	Environmental Monitoring System
FMA	Forest Management Area
FMP	Forest Management Plan
FSC	Forest Stewardship Council
GHG	Greenhouse Gases
IPCC	Intergovernmental Panel on Climate Change
MoE	Ministry of Environment, Forest Services Branch, Saskatchewan
NRCAN	Natural Resources Canada
RCP	Representative Concentration Pathway
SFI	Sustainable Forestry Initiative
SFM	Sustainable Forest Management
SOP	Standard Operating Procedure
VOITs	Values, Objectives, Indicators, Targets

CHAPTER 1: INTRODUCTION - VULNERABILITY AND ADAPTATION TO CLIMATE CHANGE IN SUSTAINABLE FOREST MANAGEMENT IN SASKATCHEWAN

1.1 Introduction

The potential effects of climate change on forests are expected to have significant implications for forest managers' ability to achieve sustainable forest management (SFM) objectives and goals as they are currently practiced (Edwards et al., 2015). For this reason, the CCFM has recommended that both consideration of climate change effects and future climatic variability is a necessity in all aspects of SFM (Edwards et al., 2015). Through the development of the CCFM guidebook, a framework for identifying vulnerabilities in SFM systems and steps to develop, then mainstream adaptation to aid in addressing climate change and climatic variability, was established. This framework is an essential tool that forest industry planners and managers can use to undertake a vulnerability assessment for their SFM to inform development and implementation of adaptation options to address the effects of climate change (Williamson et al., 2012).

The objective of this project was to examine Saskatchewan's boreal forest vulnerability to a changing climate and how this affects SFM systems. In addition, this project helped SFM practitioners apply current planning and management tools to address priority issues related to climate change (Edwards et al., 2015). These tools are available to assist practitioners in addressing the following:

- SFM vulnerability to climate change;
- adaptive capacity;
- decision-making that address a changing climate in boreal forest ecosystems;
- risk management solutions;

- mainstreaming adaptation options into the forest management and planning processes;
- building capacity and resilience within SFM systems;
- providing direction for development of government policy that will promote flexibility and collaboration among SFM stakeholders.

The Ministry of Environment in Saskatchewan has been a key collaborator in the initiation of this project by identifying the need for increased knowledge in the area of SFM and climate change. Agency staff recognize the importance of developing tools and strategies, in cooperation with industry, that will enhance sustainable forest management in an uncertain climatic future.

This project focused on the Mistik Management Ltd. forest management agreement area (FMA), located on 1.9 million hectares of Crown land in the Boreal Plain Ecozone in north west Saskatchewan. It promoted active engagement by stakeholders to provide linkages among science, planning, management and policy in Saskatchewan. However, the results of this research can be applied across Canada in building capacity in SFM. In addition, it will assist forest managers in dealing with the development and mainstreaming of adaptation options into SFM and policy. Mainstreaming involves the inclusion of climate change adaptations in day-to-day decision making, long-term planning, and management on a continuous and ongoing basis (Edwards et al., 2015). The information and tools that resulted from this research will allow forestry practitioners and stakeholders to employ user-focused solutions to SFM systems within planning and management procedures across all provinces and territories of Canada.

1.2 Purpose & Objectives

The purpose of this project was to assist SFM practitioners and policy makers in meeting their management objectives by adapting their practices to account for climate change vulnerabilities. Currently there is a gap between research, policy and practice in vulnerability assessment and adaptation planning. This project has aided in bridging the gap to provide applied tools for vulnerability assessment, adaptation planning and mainstreaming for forest managers. The results of this project will also enhance policy makers' and practitioners' adaptive capacity in meeting SFM objectives. These recommendations will continue to evolve as new approaches are tested and proven through additional research. The innovation of this project is in linking an applied case study to policies that have provided tools to practitioners and policy makers in a changing climate. Failure to acknowledge the new reality of climate change may result in widespread impacts that could be avoided or at least minimized with appropriate policy and adaptation strategies in place.

1.3 Literature Review

1.3.1 Sustainable Forest Management and Adaptation to Climate Change

As our world changes, so do the complex socio-ecological systems that we are managing. In the context of Canadian forestry, SFM is the predominant paradigm used for the management and sustainability of forests. Canadian forests contain a wealth of resources and are a complex socio-ecological system that is an integral part of the Canadian environment and economy. In 2017, the forest industry contributed $24.6 billion to Canada's Gross Domestic Product (NRCAN, 2018). Forests offer significant values socially, culturally, environmentally, and economically (CCFM, 2006). The forests of Canada also have multiple stakeholders, enrich lives, offer habitat for wildlife, hold aboriginal importance and spirituality, moderate climate, filter air, store carbon, and play a role in water quality and quantity (CCFM, 2008).

Canadian forests are managed, based on the approach of sustainable forest management. One of the main tenets of SFM is to achieve a balance between the demands placed on our forests for products and the benefits and maintenance of the health and diversity of the forest (CCFM, 2006). The Canadian Council of Forest Ministers (CCFM) has developed the over-arching mandate and goals of SFM for Canada. Canada has a wide variety of diversity within its forest types that vary across the country. Even with this type of ecological diversity, the foundations of SFM can be adapted and applied to the sustainable management of all forests in Canada. The provinces and territories are responsible for the management of natural resources, including forests (CCFM, 2008). It is their role to use the principles of SFM to develop and enforce their own legislation, standards, and programs for forest management. Provincial governments enter into agreements with forest companies that allow them to operate in their agreement area in exchange for certain obligations (e.g., regeneration practices) (CCFM, 2006).

As the global climate continues to change, it has become increasingly evident that adaptation and mitigation tools and techniques will be important to managing for the effects of climate change and upholding the principles and values of SFM (Lim and Siegfried, 2005). The term adaptation refers to the adjustment in ecological, social or economic systems in response to actual or expected climatic stimuli, their effects or impacts (Halofsky et al., 2011a). Adaptation also refers to changes in processes, practices and structures to moderate potential damages or to benefit from opportunities associated with climate change (Gitay et al., 2001). Adaptation in climate change can be spontaneous or planned, and can be carried out in response to, or in anticipation of, changes in conditions (Ogden and Innes, 2007).

To begin developing adaptation options for SFM, it is also important to understand what is meant by vulnerability (Glick et al., 2011). Vulnerability refers to the level of susceptibility a system has to changes in climate and how this system can cope with the adverse effects of climate change (Johnston et al., 2009). Vulnerability deals with the exposure of a system to climate change and the sensitivity of that system (Peterson et al., 2011). The effects of climate change may be direct (e.g., a change in tree growth in response to a change in the mean, the range, or the variability of temperature) or indirect (e.g., damages caused to trees due to an increase in insect outbreaks) (McCarthy et al., 2001).

Successful adaptation to climate change and climatic variability in SFM depends heavily on availability of appropriate technology, government policy and assistance, collaboration among academia, government and other stakeholders, and transfer and exchange of information (Edwards et al., 2015). When addressing the process of adaptation, three questions must be asked. The first question deals with who or what adapts; second, what are they adapting to; and third, how will they adapt (Smit et al., 1999). These three factors must be taken into consideration before developing possible adaptation strategies to achieve sustainability (Smit et al., 1999).

Research has indicated that projected climate change will have significant impacts on boreal forest ecosystems (Edwards et al., 2015). In order to sustain forest ecosystems, adaptation of SFM to the changing climate is necessary (Lemmen and Warren, 2004). Traditional and present practices may have to be modified in order to adapt to climate change (Kellomaki et al., 2005). The objective of adaptation in SFM is to sustain various functions of the forest ecosystem through time, to minimize the losses, enhance the benefits, and to facilitate or modify natural succession resulting from the changing climates (Krankina et al., 1997). It is important that adaptive strategies be developed and tested, and combine science, policy and management to address climate change impacts (Edwards and Hirsch, 2012). It is also important that adaptation options are flexible in order to deal with the risk and uncertainties that surround potential climate change impacts. Adaptation strategies need to include all aspects of managing the forest ecosystem including harvesting, reforestation, utilization, planning, and protective strategies (Herrington et al., 1997). Adapting SFM to potential impacts of climate change will require the recognition that there is uncertainty and risk, that our understanding of boreal forest ecosystem function will improve, and that new ways of managing for a sustainable future will be developed (Swanston and Janowiak, 2012). Prioritization of uncertainties, vulnerabilities and risks is essential for the success of adaptive management strategies as well.

Uncertainties of future climate change impacts at local and regional scales may limit the development and timely deployment of specific adaptive measures in SFM (Noss, 2001). The identification of ‘no regrets’ adaptation options, with favorable cost-benefit ratios, may help the forest sector to rank future priorities (Innes et al., 2009). Adaptation options will require improved communication between stakeholders and managers in the forest sector and the establishment of appropriate institutional and structural frameworks (such as the CCFM’s Guidebook for Assessing Vulnerability and Mainstreaming Adaptation into Decision Making, Edwards et al., 2015). Incorporating adaptive management into current forest practices and the development of an extensive forest health monitoring system are required for success (Edwards et al., 2015).

1.3.2 Sustainability Methodology, Approaches in SFM and Saskatchewan (with a focus on Mistik Management Ltd.)

The principles of sustainability guide human resource management activities so that they remain within the tolerance limits of the ecosystem. Tolerance limits include environmental conditions within a range that the ecosystem can best survive and reproduce. These are the conditions that species within that ecosystem are best adapted for (e.g. temperature). Sustainability refers to human actions that can be undertaken in a manner that does not adversely affect environmental conditions that are essential to support those same activities in the future (Parry et al., 2007). Sustainable management in the forest sector goes beyond the principle of sustained timber yield, to which the Canadian forest community has traditionally been committed (Mistik, 2007). This includes maintaining wildlife and fish habitat, watersheds and hydrological cycles, and genetic and species diversity, to ensure that the use of the forest today does not damage prospects for its use by future generations (CCFM, 2006). The task confronting the government and the forest sector is to identify what adaptive management is and how can it be applied in the form of adaptation options for the sustainable management of the boreal forest (Johnston et al., 2006).

In Canada, the management of forests is the responsibility of the provinces and territories (CCFM, 2006). Each province has its own legislation, regulations, standards, and programs through which it allocates harvesting rights and management responsibilities (CCFM, 2008). In Saskatchewan, the concept of SFM is based on the constraints of productive and assimilative capacity of the environment (Mistik, 2007). It is important to realize that differences in philosophies and approaches to forest management exist between companies and government. However, the general principle is to undertake management practices that do not adversely affect environmental conditions (e.g., soil, water quality, biodiversity, etc.) and will support those same management and planning activities in the future (Spittlehouse and Stewart, 2003). Each company demonstrates its differences in approaches by providing a statement of their strategies in their long-term forest management plans. The plans illustrate how they fit within the framework of SFM principles and are reviewed by the provincial government.

In Saskatchewan, the forest companies are required by the provincial government to submit a detailed forest management plan that is built on the general principles of SFM. Mistik Management Ltd., a forest company in Saskatchewan, also states that part of their mandate is aimed at maintaining and enhancing the long-term health of forest ecosystems, while providing ecological, economic, social, and cultural opportunities for the benefit of present and future generations. This includes integrated resource management, adaptive management, conservation of soil and water, and maintenance of biological diversity across the broad landscape and ecosystem processes (Mistik, 1999).

The Saskatchewan Ministry of Environment requires that FMA holders implement SFM that is dynamic and flexible. It must reflect society's changing needs and incorporate new knowledge of the boreal ecosystem into the planning and management process. The Saskatchewan Government requires that all forest companies base their management plans on the guiding principles of SFM, set forth by the CCFM (Province of Saskatchewan, 1996).

1.3.3 Role of the Canadian Council of Forest Ministers (CCFM) in Sustainably Managing Canada's Forests

The Canadian Council of Forest Ministers is made up of fourteen federal, provincial and territorial ministers of forestry from across Canada (CCFM, 2008). The CCFM oversees Canada's vast forests and provides general guidance for sustainable forest management in Canada. The CCFM is committed to sustainable forest management, which aims to maintain and enhance the long-term health of forested ecosystems while providing ecological, economic, cultural, and social opportunities for present and future generations (Peterson and Hirsch 2015). Over the years, the CCFM has developed the guiding mandate and goals of SFM that have allowed the provinces and territories to sustainably manage their forest resources. Forests are complex socio-ecological systems and management for sustainability can be a very difficult task.

The concept of sustainable forest management was developed in response to this need for a sustainable approach to the management of this system while learning from and working with various disciplines that are all a part of this complex system (Ohlson et al., 2005; Edwards and Hirsch, 2012).

As the changing climate has become one of the main areas of focus for the CCFM, many researchers, policy makers, forest practitioners, and other stakeholders have begun to realize that adapting forest management policies and practices is necessary. However, they also realize that SFM is a complex system of management and requires an interdisciplinary team to accomplish this goal. Therefore, adaptation of SFM is required. The CCFM also has a task force that focuses specifically on addressing climate change and future climatic variability in the Canadian forest sector (Williamson et al., 2012). The Climate Change Task Force is a federal/provincial/territorial group composed of government representatives and policy makers. They collaborate with forest managers and other stakeholders on adaptation in SFM (Peterson and Hirsch, 2015).

1.3.4 Boreal Forest

The boreal forest began to form after the retreat of the glaciers approximately 10,000 years ago. It covers almost one third of the country's land mass and contains approximately three-quarters of its forested area (CCFM, 2008). The boreal ecosystem is a diverse landscape that contains approximately 12 conifer and deciduous tree species. Many species have transcontinental distributions and are adapted to withstand extremes of climate and to regenerate after fire, insect and disease disturbance (Kirschbaum and Fischlin, 1996). However, this may change with the anticipated changes in climate within the forest. For example, McKenney et al. (2007a, b) used climate model-scenarios to simulate projected changes in tree distribution across North America.

With a changing climate, some examples of expected impacts on the boreal forest include reaching/exceeding thresholds for tree growth, reproduction, and survival at given sites (Kasischke et al., 2010). The climate sensitivities in the boreal forest may lead to an increase in the severity of droughts causing an increase in the incidence and severity of fire disturbances (Stocks et al., 1998). Changes in fire or storm frequencies are likely to have significant impacts on the composition, age-class distribution, and biomass of the boreal forest (Kirschbaum and Fischlin, 1996). Overall, the boreal forest is expected to decrease in area and biomass, with a move towards a younger age-class distribution and considerable disruption, especially at its southern boundary (Zhang et al., 2014). A shift from conifer dominance to hardwood dominance in mixed wood areas is also likely (Girardin et al., 2013).

1.3.5 Disturbance Regimes in the Boreal Forest and Climate Change

The boreal forest is expected to be dramatically altered by a variety of disturbance agents due to climate change. Disturbances are widespread and important aspects of the life cycle of the boreal forest ecosystem. In the boreal forest, disturbances such as fire, wind, insects, and disease play an important role in the functioning of the ecosystem (Flannigan and Bergeron, 1998). Examples illustrating this in Canada include:

- In 2017, approximately 3.4 million hectares of forests burned, which was well above the average annual area burned (NRCAN, 2018).
- In 2016, 15.5 million hectares of forest were affected by insects (NRCAN, 2018).

These disturbances must be taken into consideration when attempting to understand how future changes in climate may affect the boreal forest (Flannigan and Bergeron, 1998). Direct effects of changes in temperature and water availability may lead to indirect effects on fire, insects, and disease disturbances (Pastor and Post, 1988). The Western Canadian boreal forest is very sensitive to these impacts (Edwards et al., 2015). Disturbances such as fire, insects, and disease are important factors in the health and growth of existing boreal forest ecosystems as well as in the success of future restocking efforts (Kasichke and Turetsky, 2006).

1.3.6 Vulnerability Assessment

Over time, research surrounding vulnerability of social and natural systems has become increasingly complex. Many of these systems have biophysical components that are based on science and also on social elements that are more subjective in nature (Glick et al., 2011). The literature demonstrates that research interests and perspectives related to vulnerability have shifted to include climate change and uncertain climatic futures (Cannon and Muller-Mahn, 2010). The literature also highlights the strong linkage between vulnerability, adaptive capacity and resilience of systems and the convergence of these elements due to a consistent focus of research, and analysis on socio-ecological systems (Adger, 2006). This shift includes the concept that human actions and social structures are linked with natural systems. These linkages require that all of these complex issues be taken into consideration when analyzing the vulnerability, adaptive capacity and resilience of a system. This leads to a melding of the human and natural systems, leading to a complex socio-ecological system (Adger, 2006).

Natural (ecological) and social systems have distinctly different elements. Natural systems deal mainly with the biological and biophysical processes. Social systems include components such as rules, institutions, economics, cultures, values/ethics, and knowledge. The structure of the social system determines how humans interact, value, and use the natural system and its resources (Berkhout et al., 2002). It is clear that socio-ecological systems are indeed complex. When assessing vulnerability, adaptive capacity and resilience, many different disciplines must be drawn on to contribute knowledge, understanding, and information. (Hinkel et al., 2013).

As research develops in the fields of climate science, vulnerability assessments, and policy, it is important to realize that there is no single “right or perfect” approach and that each system is unique in its requirements (Glick et al., 2011). Whatever assessment method is used, there must be a firm understanding from the users as to the outcomes that are sought, which will help in choosing the assessment that is the ‘best fit’ for that system (Glick et al., 2011).

Vulnerability research and assessment has emerged as an important tool that informs climate change science and policy development (Füssel and Klein, 2006). After reviewing a substantial amount of literature surrounding vulnerability, the definition that seems to have emerged as most prevalent is from the Intergovernmental Panel on Climate Change (IPCC): vulnerability is the degree to which a system is susceptible to and is unable to cope with adverse effects of climate change, including variability and extremes (McCarthy et al., 2001). When assessing vulnerability, a system may be vulnerable, but can continue to cope with the adverse effects or stressors until it has gone beyond certain thresholds. According to the IPCC, vulnerability is a function of exposure, sensitivity and adaptive capacity (Adger, 2006).

Research on climate change and vulnerability assessments has been approached in a variety of contexts. According to Füssel and Klein (2006), vulnerability assessments are done for a diverse group of stakeholders and users that are motivated by a wide array of concerns. The IPCC assessment reports (e.g. IPCC, 2014a) reflect how the process of assessing climate change has made use of theory and methods for assessing complex socio-ecological systems. As with many vulnerability assessments, those that are focused on climate change are interdisciplinary in nature and include the biophysical and social/economic impacts of climate change. The IPCC reports also demonstrate that assessments are related to stakeholder’s needs. These assessments are science and policy driven and consider climate change impacts as well as potential adaptation options (IPCC, 2014a). This is an integrated, interdisciplinary approach, showing an evolution in the development of climate change vulnerability assessments that is similar to vulnerability assessments in other fields and development of integrated assessments (Füssel and Klein, 2006). Füssel and Klein (2006) have outlined three major decision contexts that are used in climate change vulnerability assessments. These include:

- Specification of long-term targets for the migration of global change;
- Identification of particularly vulnerable regions and/or groups in society to prioritize resource allocation for research and for adaptation (both nationally and internationally);
- Recommendation of adaptation measure for specific regions and sectors.

The main components of climate change vulnerability assessments are used to develop adaptation options that will help increase adaptive capacity and resilience of the system. Mitigation for climate change usually focuses on reducing Greenhouse Gas (GHG) emissions and increasing carbon sinks (Füssel and Klein, 2006). Adaptation and mitigation involve the development of options designed for and integrated into management planning and operations (Füssel and Klein, 2006). They also aid in projection or anticipation of changes to ecosystem composition, structure and function as well as socio-economics of a system (Berkhout et al., 2002). This combination is an essential element of the success and strength of climate change vulnerability assessments. Given the uncertainty of temperature changes into the future, a variety of climate model-scenario tools have been developed in countries around the world and are used in various combinations by the IPCC and jurisdictions to explore potential adaptation and mitigation options. However, due to the complexity of these systems, scenarios are also used to help increase the confidence in understanding the climatic future, and the impacts on the system. There is still a great deal of uncertainty to adapt to (Berkhout et al., 2002). Climate change assessments also have a role to play in policy as a way of examining the adaptive capacity of different sectors and directing policy to assist in increasing the adaptive capacity of these sectors and increasing stakeholder and societal awareness (Berkhout et al., 2002).

1.3.7 CCFM Vulnerability Assessment

The Canadian Council of Forest Ministers has developed a conceptual framework that focuses on assessing vulnerability, adaptive capacity and developing and mainstreaming adaptation options with respect to climate change (Williamson et al., 2012). The foundation of the vulnerability assessment is the IPCC approach discussed above.

Research shows clearly that Canadian forests and their management will be affected to varying degrees by climate change (Johnston et al., 2009). The current SFM system is based on a historical approach to climate and assumes that forests will continue to grow under a climate similar to that in the past. However, it is increasingly apparent that forests will be affected to varying degrees by climate change (CCFM, 2008). The CCFM approach to vulnerability assessment was developed to increase forest managers' understanding and provide tools that will assist them in incorporating climate change into SFM (CCFM, 2008).

The CCFM approach assists forest managers in identifying how their SFM system is vulnerable to climate change, determining the overall adaptive capacity of their system, and aids in the development and mainstreaming of adaptation options into their planning and management (Edwards and Hirsch, 2012). This approach for assessment considers both human and natural elements of the SFM system and the potential impacts of climate change on Canadian forests. The CCFM approach has the following key components:

- It establishes a direct linkage between vulnerability assessments and adaptation decision making.

- It promotes input from a wide range of experts, including scientists, forest managers, policy makers, and local stakeholders.
- It facilitates learning and the exchange of information and knowledge.
- It is applicable at different temporal and spatial scales, and in different organizational contexts.
- It adopts a forward-looking approach, while acknowledging and accounting for uncertainty, and the need to develop and implement adaptation measures that will be robust in an uncertain future.
- It embraces a systems-based approach that is applicable to complex, cross-cutting, dynamic, and interactive issues related to SFM and climate change (Williamson et al., 2012).

The CCFM assessment framework is composed of six main actions (Williamson et al., 2012):

1. provide the context for the assessment;
2. describe current climate and forest conditions;
3. develop scenarios of future climate and forest conditions;
4. assess the vulnerability of SFM to current and future climate;
5. develop and refine options for adaptation; and
6. implement and mainstream options for adaptation.

The first three actions in the CCFM framework make up a pre-vulnerability assessment that helps to lay the foundation for the more detailed part of the assessment, which is step four (Williamson et al., 2012). Steps five and six focus on the development, applicability and implementation of adaptation options. The vulnerability assessment is scalable and can be used in any ecosystem type under different management and policy systems (Williamson et al., 2012).

The vulnerability assessment is not an end-point; it is a continual part of SFM. As new information becomes available, vulnerabilities change and priorities are altered. The vulnerability assessment becomes part of the ongoing process of SFM in continual day-to-day planning, management and operations. When managing any natural resource, it is important to remember that these are not static environments and neither is planning and management. Elements may require modification or adaptation options and may need to be changed or re-adapted on an on-going basis (Williamson et al., 2012).

1.3.8 Adaptation

Changes in climate affect environments and systems at a variety of spatial and temporal scales. The complexity of this is increased when considering local, regional, and national levels of government, policy, economics, and social/human dimensions within these systems (Noss, 2001). Stakeholders need to start preparing for climate change and adapt multiple elements for the social, economic and ecological consequences of these impacts, and at the same time identify and take advantage of any potential opportunities (Lemmen and Warren, 2004). This is the underlying premise of adaptation with respect to climate change.

Adapting decision and policy making for addressing climate change impacts will help increase the ability of mangers to implement adaptations (Peterson et al., 2011). Adaptations can also be at varying levels, from individual or group, to policy makers, and technical staff. It is also important that adaptation be evidence-based to support decision making that will be consistent and flexible (Williamson et al., 2009).

In the field of climate change, adaptation planning usually follows vulnerability assessments and is based on the vulnerabilities identified by these assessments. Adaptations need to be developed based on the evidence that is specific to that system (Johnston and Edwards, 2013). There is no "one size fits all" approach to adaptation, and there is not one standard "shopping list" of adaptation strategies (Halofsky et al., 2011a). Adaptation strategies that have been developed for one system can be guides to get ideas flowing for the development of adaptation strategies in a different system (Swanston and Janowiak, 2012).

1.3.9 Approaches to Adaptation

When planning for the future, uncertainty will always be a predominant factor (Walker et al., 2013). The literature on adaptation and climate change discusses different ways of dealing with uncertainty. A common theme however, is that many of the approaches for adaptation were developed in a research environment, and there is limited evidence of the integration and mainstreaming of adaptation in practice (Lim et al., 2005).

In many approaches to adaptation, there are linkages between natural hazards and human health risk methodologies, especially in the use of risk management methods as part of the evolving adaptation process with respect to climate change (Ohlson et al., 2005). Through the development of adaptation in climate change, there has been a shift to a more structured-decision making, risk-based approach with the use of integrated vulnerability assessments (Ohlson et al., 2005). In the structured decision-making and risk management approach, adaptation strategies can be developed at different levels, such as local, regional, or national. Many approaches for adaptation also require an evaluation of costs and benefits of different adaptation strategies for the system (IPCC, 2007a).

Evidence-based decision-making is another common approach to climate change adaptation. This form of decision making provides a consistent and flexible approach to assess vulnerability to climate change impacts, risk analysis, identify options for adaptation and build organization capacity (ESRD, 2010). This approach is based on science and other sources of evidence (e.g. management techniques) that provide robust adaptation options. The options address the economic, social and ecological elements of a system that can threaten the ability of an organization to achieve objectives, outcomes and goals in the face of climate change (ESRD, 2010).

Many of the approaches to adaptation use elements from risk-based management. Risk-based approaches aid in directing investments and resources towards areas that are considered priority risks and vulnerabilities for that system (ESRD, 2010). This approach attempts to limit costly disruptions and safeguard the economic and social health of an organization or system (ESRD, 2010). Risk Management or Enterprise Risk Management "is an integrated tool to enable decision-makers to effectively address uncertainty and respond appropriately to risks and potential opportunities" (ESRD, 2010). Risk-based management is intended to aid organizations in addressing potential climate change impacts and their risks or vulnerabilities in a comprehensive manner. Climate change is another risk that is part of the overall risk-based management approach.

Another approach to adaptation to climate change is the ecosystem management approach. Ecosystem management has been practiced on landscapes and waterscapes since the late 1980s and provides a foundation for addressing many climate change effects (Peterson et al., 2011) within natural environments. Ecosystem management, like many of the other techniques described in the adaptation literature is interdisciplinary in nature and consist of an analysis of the ecosystem as a whole at large spatial scales (Peterson et al., 2011).

When taking any approach to adaptation to climate change, systematic monitoring and evaluating to detect changes and determine the success of adaptive management activities is also important (Halofsky et al., 2011a). Monitoring provides the feedback needed to constantly assess change and the associated human responses to that change and evaluating adds to the robustness of adaptation and helps keep the system more resilient and increases the adaptive capacity (Walker et al., 2013). As adaptation research has evolved, its applicability with respect to climate change adds dimensions of organizational and cultural challenges along with ecological ones (Halofsky et al., 2011b).

It is important to note that the different approaches to adaptation contain both anticipatory and reactive approaches to adaptation. Both planned and autonomous adaptation are usually part of the approach. Planned adaptation is the result of deliberate decisions, based on an awareness that conditions might change or have changed, and that action is required to return to, maintain or achieve a desired state. The following is an example of planned adaptation from the Mistik case study:

- CCFM SFM Criterion: Biological diversity; Climate Change Impact/Vulnerability adapting to is alteration of plant and animal distribution, at the strategic SFM level; adaptation is to provide buffer zones for adjustment of reserve boundaries (Mistik, 2017).

Autonomous adaptation is adaptation that is not a planned external response to a situation but is an internal system reaction due to changes within the system (can be referred to as resilience) (Walker et al., 2013). The following is an example of this form of adaptation from the Mistik case study:

- Sudden change in weather events causing issues with access to active winter harvest sites, causing operations to move to areas that were alternately scheduled for summer harvest operations (Mistik 2016).

Throughout the adaptation literature, it is evident that many of the approaches include common elements and stem from the foundations of natural hazards and risk assessment. When choosing a method for adaptation, it comes down to the members of the adaptation team, their objectives and the elements of the approach being used (Halofsky et al, 2011a).

1.3.10 Adaptation and the CCFM Approach

The approach to adaptation that is of particular interest for this research project is that developed by the CCFM. In the face of climate change, building knowledge, assessing vulnerability and developing adaptation options are required to support SFM policy making and management decisions (Edwards and Hirsch, 2012). It is clear, based on climate change impacts research, that the risks to SFM goals and objectives will be significant. The policies and practices need to evolve to include flexible, robust adaptation options for future climatic uncertainty (Williamson et al., 2012). The CCFM approach provides a number of tools and products to "enhance the capacity of the Canadian forest sector to adapt to climate changes" (Edwards and Hirsch, 2012). One of the biggest challenges is that of uncertainty and how to best plan and adapt to potential climate change impacts.

The CCFM approach is built on a flexible, broad framework that will enable forest managers to better understand how SFM is vulnerable to current and potential future climatic conditions and how such information can be incorporated into adaptation decision making on an ongoing basis (Edwards and Hirsch, 2012).

Through this approach, adaptation will be mainstreamed into all elements of SFM and it will build capacity and resilience within the system. The CCFM approach is based on the following foundational pieces (Edwards and Hirsch, 2012):

- Climate change and future climate variability should be considered in all aspects of SFM in Canada.

- Systematically evaluating organizational readiness prepares organizations, whether public or private, for the challenges of climate change adaptation.
- Assessing the vulnerability of SFM in Canada to climate change at different scales (from local to national) can lead to more effective and efficient adaptation decision making.
- Using scenarios can help forest managers and other stakeholders to develop robust adaptation plans and to identify "no-regret" adaptation options and will inform decision making for an uncertain future.
- SFM planning in a changing climate requires decision making based on adaptive management or continuous improvement practices that include sound science and analyses, as well as expert opinion, the use of climate-relevant indicators, and systems to measure and track the effectiveness of adaptation actions.
- The capacity of the forest sector to adapt to climate change will be strengthened by new research and development related to climate change adaptation, by inter-organizational collaboration and cooperation, and by the sharing of adaptation knowledge, experiences, best practices, and lessons learned (Edwards and Hirsch, 2012).

The health and sustainability of Canada's forests is vulnerable to climate change (Ohlson et al., 2005). As climate change continues to occur, current and potential impacts are, to varying degrees of magnitude, a certainty for Canadian forests. It is also important to understand that SFM goals and objectives may be harder to achieve in the future in the face of climate change (Swanston and Janowiak, 2012). With the CCFM approach described above, the forest sector's adaptive capacity will be increased, and systems will be more resilient to climate change. This approach to adaptation is forward-looking and includes systems thinking, providing the ability to make informed decisions for adaptation despite uncertainties surrounding climate change and their impacts (Edwards and Hirsh, 2012).

1.3.11 Adaptation and Policy

As the field of adaptation research has evolved and expanded over time, it is evident that flexible policy is important for the development of adaptation options. Adaptation to climate change presents challenges to existing policy, regulations, institutional structures and governance (Halofsky et al., 2011a). As climate change continues to occur at different spatial and temporal scales across the globe, there is a need to adapt management and policy measures to minimize negative impacts, and to maximize the potential benefits that may come out of climate change (Innes et al., 2009). Policies often serve multiple purposes and have not traditionally been introduced specifically in response to climate change (Innes et al., 2009). Policy support is very important to successful implementation and mainstreaming of any adaptation measures for SFM (Kolstrom et al., 2011).

Policy formulation can promote and assist in moving towards adaptation and implementation to address and manage for climate change (Eisenack et al., 2014). Regulations can aid in the enforcement of adaptation; however, many current regulations don't deal specifically with climate change. Unsuitable policy for adaptation, along with insufficient means of enforcement, plays a role in limiting adaptation development and implementation (Innes et al., 2009). There has been some progress on working towards a shift in thinking about policy that will be more flexible and promote climate change adaptation. Current aims for policy change for adaptation include: to raise awareness of adaptation; to facilitate and strengthen the capacity for coordinated action on adaptation; to incorporate adaptation into policy and operations; promote and coordinate research on impacts and adaptation; to support knowledge-sharing networks; and, to provide tools for adaptation planning (Innes et al., 2009). However, translating the science of climate change impacts and vulnerabilities into on-the-ground adaptation options and policy has not kept pace (Nelson, 2012). It is also important to understand that policy makers want practical, low cost, low-risk ways to address climate change impacts and adaptation needs (Ohlson et al., 2005).

Adaptation for climate change is very complex; however, policy-makers are starting to include general information on vulnerabilities in policies and regulations. The problem is the generality of this information, and that most often adaptation is still reactive rather than proactive. “Policies at international, national and regional levels must all aim to improve the adaptive capacity of society” (Kolstrom et al., 2011).

Many factors come into consideration in regulation and policy development and change. Societal values, objectives, economics, and risk perception are extremely influential in this process (IPCC, 2014b). There is a direct link between science and policy, and planning and decision making (Williamson et al., 2009). Adaptation plans and policies are moving towards integration with regulations and existing policies to help enhance the capacity of systems to address climate change impacts and manage these complex socio-ecological systems.

1.3.12 Mainstreaming of Adaptation

To assist in the mainstreaming of adaptation options, it is very important to disseminate ideas quickly and to the right managers and stakeholders in order to advance thinking and practice (Halofsky et al., 2011a). Mainstreaming also allows for the opportunity to make more effective use of financial resources rather than designing, implementing and managing climate change adaptation and policy separately from day-to-day planning and operational activities (Innes et al., 2009). Mainstreaming climate change adaptation can also lead to more robust planning and management to reduce the risks and maximize opportunities (Edwards et al., 2015). This will lead to increasing the adaptive capacity and resilience of systems that are vulnerable to climate change (Spittlehouse, 2005).

Implementing adaptation options demonstrates a more proactive approach to planning and management that can be integrated into existing management frameworks. It is also important to recognize that a "critical component of adaptation mainstreaming is a rigorous, and goal, or indicator-oriented monitoring system" to determine if management techniques are having the desired effects (Biringer, 2003). This is a continual process and the following should be considered:

- adaptations are assessed by the degree to which they are effective;
- technical feasibility and costs and benefits are evaluated;
- adaptations that are feasible and economically justified are implemented;
- the performance of the adaptation is monitored and evaluated;
- the adaptation program and/or management objectives are modified, if necessary; and,
- vulnerability is periodically reassessed as new knowledge, learning, and insights become known." (Williamson et al., 2012).

Continual monitoring and evaluation also provides users and managers with the information to make changes and adapt options to be more effective and suitable moving forward. It is important to understand that adaptation development and mainstreaming is not an 'end-point' in the process of managing in the face of climate change (Edwards et al., 2015); it is continual. In moving forward for successful mainstreaming of climate change adaptation into everyday planning and operations, it is imperative that users and managers be engaged and committed to the process.

1.3.13 Adaptation Challenges/Barriers

Challenges and barriers to management planning and decision making are all part of the process within SFM. However, they can make adaptation less effective or efficient, or costlier (Moser and Ekstrom, 2010). Managing uncertainty can be one of the biggest challenges for adaptation, especially that associated with the magnitude of climate change impacts (Halofsky et al., 2011a). Uncertainty can be overwhelming and lead to the development of barriers and delays in developing and mainstreaming adaptation options. Moser and Ekstrom (2010) describe barriers as obstacles that can be overcome with concerted effort, creative management, change of thinking, prioritization and related shifts in resources, land uses and institutions. The following lists challenges and barriers regarding development, implementation, and mainstreaming of climate change adaptation options into SFM (IUFRO, 2009):

- Adaptation has not occurred yet;
- Change in government (local, regional, provincial, federal);
- Competing priorities and competition for resources and funding;
- Lack of commitments and agreement from all involved;
- Lack of knowledge, steep learning curves;
- Policy constraints and lack of policy flexibility;
- Lack of sufficient regulations for enforcement;
- Preconceived bias of those involved in the development, planning and implementation processes;
- Managing uncertainty;
- Public perception (Halofsky et al., 2011b);
- Managers lack strategies for adaptation to climate change (Halofsky et al., 2011a);
- Ethical limitations to some adaptations (e.g., altering ecosystems) (IPCC, 2014a).

In the process of adaptation, it is important not to let challenges or barriers guide and dictate development and exploration of adaptation. However, barriers and challenges do exist to varying degrees within different systems and it is important to be aware of them in order to overcome them. It is also important to understand where the barriers originate and how they are impeding adaptation and mainstreaming (Moser and Ekstrom, 2010). By understanding barriers and challenges, users and managers can work to overcome these obstacles to move forward. If users and managers allow barriers to prevent adaptation from happening, that in itself is a barrier (Moser and Ekstrom, 2010).

1.4 Conclusion

Even though climate change adaptation tools and techniques have rapidly evolved in the last two decades, integration or mainstreaming adaptation into SFM has not kept pace when compared to other disciplines. There are many communities and systems that have been practicing forms of adaptation throughout history. Examples of this include:

- Community-based disaster risk reduction,
- Famine early warning signs,
- Crop and livelihood diversification,
- Supplementary irrigation (IPCC, 2007).

Adaptation in itself is not a new theory (Innes et al., 2009). However, there is evidence of local adaptation that has not been well documented or directly linked to adaptation to climate change. Links between climate change impacts and adaptation are becoming increasingly evident and the need for adaptation options in the face of climate change is becoming more of a priority (Lim and Siegfried, 2005). Climate change poses a number of challenges to users, managers, and policy makers, especially in terms of dealing with the uncertainty of the future climate impacts and the varying degrees and magnitude of potential impacts (Edwards and Hirsch, 2012).

Moving forward in climate change adaptation, areas that require more research include:

- The development of innovative approaches to adaptation and tools that support decision making in a changing climate are essential for the future of SFM;
- Proactive and collaborative efforts that will promote adaptation development and mainstreaming;
- Ways to share knowledge and disseminate information about impacts and adaptation with the appropriate users, managers, stakeholders, and policy makers;
- Reporting and collecting of data and results through monitoring programs to strengthen and improve climate change adaptation evidence and examples;
- Flexibility in policy and regulation that will allow managers to address climate change issues;
- Approaches for dealing with challenges and barriers that may prevent adaptation development and mainstreaming for climate change.

Climate change impacts are becoming more of a priority to address, and changes within systems are required for future sustainability. It is also becoming increasingly clear that an uncertain climatic future is inevitable, especially for those users, managers, and stakeholders of systems that are more sensitive and vulnerable to climate change impacts already. SFM will need to adapt in order to be sustainable. Effective adaptation to climate change is contingent on the availability of two important prerequisites: information on what to adapt to and how to adapt, and resources to implement adaptation measures (Füssel and Klein, 2006).

1.5 Dissertation Structure (Manuscript Style)

This dissertation is written in manuscript style and includes three stand-alone manuscripts bookended by an introduction and conclusion chapter. It follows the guidelines as set out by the College of Graduate Studies and Research. Following the introductory chapter, the thesis is organized into three manuscripts, each of which is presented as a single thesis chapter. The Introduction is mainly composed of a literature review and provides an overview of the current state of knowledge that directly relates to the research. It also focuses on linkages, gaps and areas where more research is required to expand understanding and bridge the knowledge gap. The Introduction helps explain the dissertation format and briefly introduces each of the manuscripts. It also addresses the purpose, needs, and objectives for this research project and how the results enhance the current state of vulnerability, adaptation, mainstreaming and policy within forest management and policy.

The Vulnerability Assessment and Case Study is the first manuscript (Chapter 2) and it presents the CCFM approach that was used for the Mistik case study, describes Mistik Management and their role in the Saskatchewan forest sector, and how they have collaborated with the provincial government for the case study. The process and results of the case study are discussed and show how this has increased the knowledge and understanding of Mistik, the forest industry, and government in moving towards increasing their adaptive capacity and resilience. The experience of applying the CCFM approach, what worked and what did not, and lessons learned are key elements in this manuscript.

The second manuscript is on Adaptation and Mainstreaming (Chapter 3) and is based on the results of the case study. It discusses the assessment and prioritization of Mistik's SFM system objectives and how adaptation options were developed, ranked, and mainstreamed into Mistik's SFM strategic and operational planning. It also discusses how adaptation will be monitored and modified, both through annual operating plans and through the 20-year Forest Management Plan. Barriers and challenges to adaptation and how they were overcome is explored. The application and importance of how the vulnerability assessment increased Mistik's ability to implement "best management practices" to achieve SFM in the face of an uncertain climatic future is discussed.

The third manuscript is on Governance and Policy (Chapter 4) and identifies the roles of Mistik Management and the Forest Service Branch of Saskatchewan Environment in the case study. It discusses how they have collaborated throughout the project, and how the results of the research will assist policy makers in building responsiveness and flexibility into provincial SFM policy and regulations. It also discusses how this collaboration has increased the adaptive capacity of the government so that it will be better equipped to address climate change and SFM. Barriers and challenges for government and practitioners are also discussed along with suggestions for approaching climate change adaptation and mainstreaming within policy in the future.

The thesis ends with the Conclusions (Chapter 5) and demonstrates the linkages between the elements of the dissertation and highlight how the results have enhanced the approaches to assessing vulnerability in Saskatchewan by developing and mainstreaming adaptation options into SFM planning and management.

1.6 Copyright and Author Permission

Chapters 2 through 4 of this dissertation consist of manuscripts that are being submitted for publication. For all manuscripts, as per the College of Graduate Studies and Research guidelines for manuscript style theses, the student is the first author. The following is a list of all authors for the each of the three manuscripts:

- Chapter 2: Andrews-Key, S., Johnston, M., Edwards, J., & Laroque, C.
- Chapter 3: Andrews-Key, S., Johnston, M., Edwards, J., & Laroque, C.
- Chapter 4: Andrews-Key, S., Rayner, J., & Laroque, C.

PREFACE TO CHAPTER 2: ASSESSING CLIMATE CHANGE VULNERABILITY: CASE STUDY OF MISTIK MANAGEMENT LTD., SUSTAINABLE FOREST MANAGEMENT SYSTEM IN NORTH WESTERN, SASKATCHEWAN

The first objective of this thesis was to undertake a climate change vulnerability assessment, using the CCFM framework, with forest managers in a "real world" situation. Through this assessment, we were able to form a collaboration among government, forest industry managers, First Nations, and other stakeholders who live and/or work in the study area. The CCFM framework for assessing vulnerability and mainstreaming climate change into SFM provides a structured decision-making approach (Edwards et al., 2015). This approach allows the practitioner to engage in a step-by-step process that generates a statement of purpose, objectives, and context for the vulnerability assessment; understanding of current and future climate related relationships and scenarios; a detailed assessment of climate change effects on the SFM system; and, adaptation options designed to enhance adaptive capacity (Edwards et al., 2015).

The vulnerability assessment was completed collaboratively with forest managers at Mistik Management Ltd, a forest company in Meadow Lake and the provincial government, in Saskatchewan. This is the first complete 'real world' climate change vulnerability assessment using the CCFM framework on a commercial forest landbase through a government-industry collaboration in Canada. The project was developed to assess climate change impacts and vulnerabilities to SFM and to develop adaptation options to be mainstreamed into local SFM planning and practices. The company's SFM vulnerabilities were determined, adaptation options identified, and an approach to mainstreaming these into SFM decision making was developed. The results of this work are also important for informing and guiding provincial forest policy and regulations for climate change adaptation.

CHAPTER 2: ASSESSING CLIAMTE CHANGE VULNERABILITY: CASE STUDY OF MISTIK MANAGEMENT LTD., IN NORTH WESTERN, SASKATCHEWAN

2.1 Introduction

Canada contains 28% of the world's boreal forest (NRCAN, 2018). The boreal ecosystem is also an integral part of Canada's economy, natural environment, history, and culture. With changes in climate, the boreal forest is expected to be significantly affected at both regional (e.g. Saskatchewan) and national levels (Krankina et al., 1997). In order to manage Canada's boreal forest sustainably, researchers and forest managers have been collaborating to address the impacts of climate change (Spittlehouse 2005). The impacts of climate change may pose both opportunities and challenges for Sustainable Forest Management (SFM) (Halofsky et al., 2011a).

With the inherent uncertainties of climate change impacts, meeting the goals of SFM will become increasingly complex (Ohlson et al., 2005). Sustainable forest management includes ecological, economic, social, and cultural values that the boreal forest provides (CCFM, 2008). To achieve sustainability, forests are managed for future generations, while accounting for a balanced, equitable, and efficient flow of ecological, economic, social, and cultural benefits for current generations (Edwards et al., 2015). Climate change and the uncertainty it brings to the already complex management of forests requires re-thinking the way forests are managed (Edwards et al., 2015). Many factors drive sustainable forest management planning and practices, including economics, environmental health, and social well-being (Marchi et al., 2018). Incorporating climate change adaptation into planning and practices will be a key element to aid forest managers in addressing climate change impacts (Ogden and Innes, 2007).

The project presented in this chapter was developed to assist forest managers in their work to incorporate climate change and adaptation into all elements of their SFM system. We used a conceptual SFM adaptation framework and guide book developed by the Canadian

Council of Forest Ministers (CCFM) (Williamson et al., 2012; Edwards et al., 2015). This approach was developed to help Canadian forest managers identify the effects of climate change on forest ecosystem assets in their FMAs, assess their adaptive capacity, and develop adaptation options that could be mainstreamed into their planning and management (Halofsky et al., 2018). The project is the first to apply the CCFM approach with a forest industry partner in Canada. This testing of the CCFM approach provides an example that others may elect to follow, and illustrates how the CCFM framework can be applied at the FMA level. This chapter focuses on the application of the first three phases of the CCFM approach. Chapters three and four discuss incorporating adaptation into SFM planning and decision making, and the governance and policy implications of managing for climate change. The project was based on a case study with Mistik Management Ltd., a forest management company that holds a Forest Management Agreement with the provincial government in Saskatchewan, Canada.

2.2 Methodology

2.2.1 Background/Context

In December 2014, the Saskatchewan Ministry of Environment brought several representatives together from the forest industry, stakeholders and government to explore future climate scenarios and how they may affect SFM in the province. Workshop results highlighted knowledge gaps for addressing climate change impacts within SFM planning and policy. Based on the needs identified by the workshop, a case study to apply the CCFM adaptation approach was developed in collaboration with the Ministry of Environment and Mistik Management.

Mistik is a woodlands management company equally owned by two parent companies, NorSask Forest Products Inc. and Meadow Lake Mechanical Pulp Inc. (Mistik, 2007). The Mistik Forest Management Agreement Area (FMA) is located in northwest Saskatchewan and covers 1.9 million ha of boreal forest consisting of trembling aspen, balsam poplar, white and black spruce, balsam fir, white birch, tamarack, and jack pine (Mistik, 2007). They are situated in the southern half of the mid-boreal upland ecoregion, in the transition from grassland to forest (Mistik, 2007). The soils in the Mistik FMA include the following (Mistik FMP, 2007):

- Brunisolic order soils,
- Cryoslolic order soils,
- Gleysolic order soils,
- Luvisolic order soils,
- Organic order soils,
- Regosolic order soils.

The climate is characterized as a sub-arctic type (Dfc) according to Koppen's classification where winters are long and severe and summers are short and cool (< four months with a mean temperature > 10 °C) (Mistik, 2007). The mean annual temperature for Meadow Lake is 0.8 °C, with January temperatures averaging -17.2 °C, and July temperatures 16.7 °C (Mistik, 2007). The region is also characterized as dry sub-humid according in Thornthwaite's moisture classification (Mistik, 2007). Total precipitation for the Meadow Lake region averages 415 mm per year, with 317 mm and 123 cm of the precipitation occurring as rainfall and snowfall, respectively during the period 1981-2010 (Mistik, 2007). The majority of the precipitation (76%) occurs from May to September with about 75 mm occurring in the month of July (Mistik, 2007).

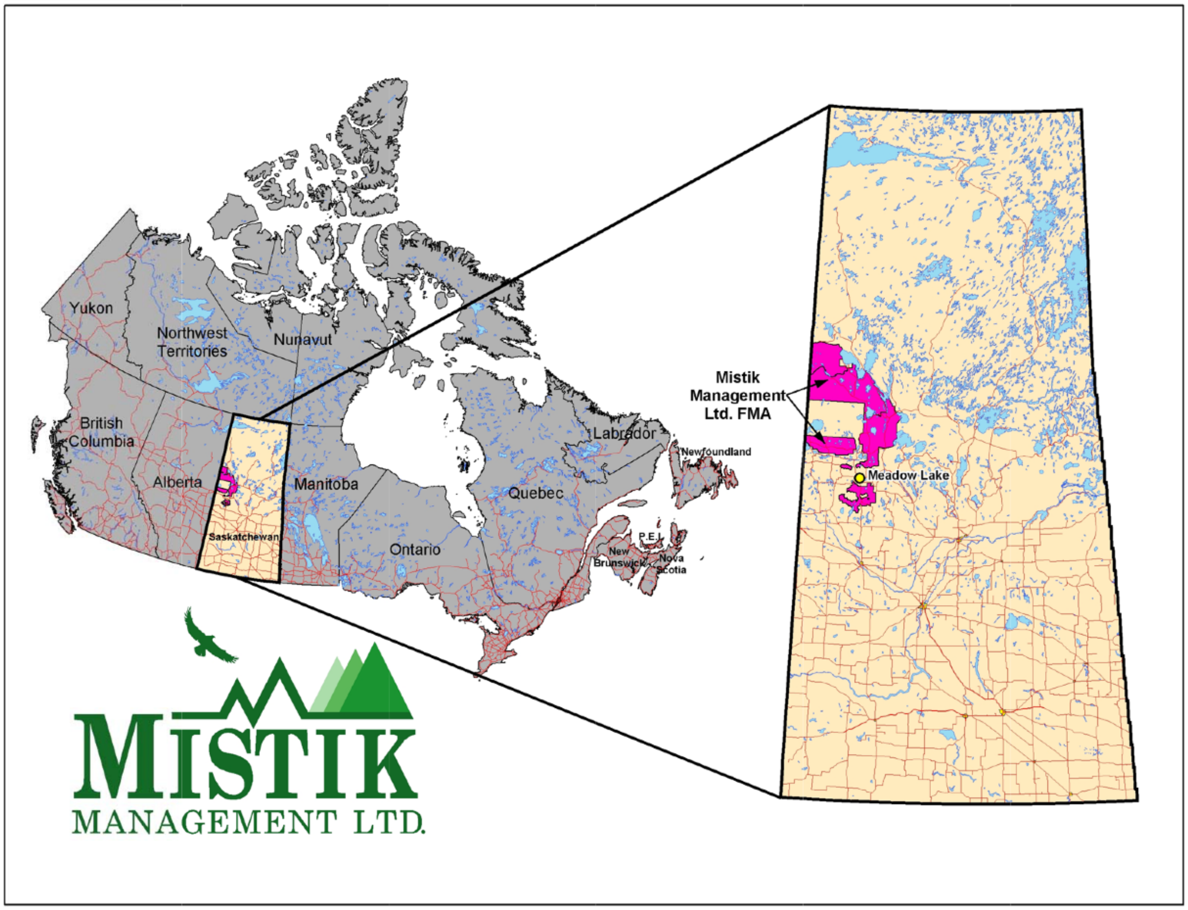

Figure 2.1 Map of Canada showing location of Mistik Management Ltd. FMA in Saskatchewan (Mistik, 2007).

2.2.2 Provincial Requirements

In Canada, the management of forests is the responsibility of the provinces and territories (CCFM, 2006). Each province has its own legislation, regulations, standards, and programs through which it allocates harvesting rights and management responsibilities to the forest industry (CCFM, 2008). The forest industry undertakes management practices that do not adversely affect environmental conditions (e.g., soil, water quality, biodiversity, etc.) and will support those same management and planning activities in the future (Spittlehouse and Stewart, 2003). Most jurisdictions in Canada require forest companies to submit long-term (e.g., 20-year) forest management plans that demonstrate how they operate within the framework of SFM principles. The plans are reviewed and approved by the province or territory.

Mistik Management Ltd. was at the start of their required 20-year forest management plan renewal when the partners for this project came together. During the plan renewal process, a forest company has additional human and financial resources allocated to this process and it is at a time where the company is thinking strategically through all aspects of their SFM planning and operations. Accordingly, the FMP renewal provided a perfect vehicle to also undertake the CCFM climate change vulnerability assessment and to begin the process of incorporating vulnerability and adaptation planning into Mistik's SFM future planning and operations.

2.2.3 CCFM Framework

The Canadian Council of Forest Ministers has worked collaboratively with researchers and managers across Canada to develop a framework for assessing climate change impacts and vulnerabilities related to SFM (Williamson et al., 2012; Edwards et al., 2015). The CCFM framework was the guiding methodology for the vulnerability assessment in the Mistik case study. This approach also follows the CCFM's Criteria and Indicators for achieving Sustainable Forest Management in Canada, which is the basis for forest management planning in Saskatchewan (Province of Saskatchewan, 1996).

Through the Mistik vulnerability assessment, we tested the applicability of the CCFM approach at the FMA level. The framework allows for a range of values to be assessed that encompass both the biophysical and socioeconomic aspects of SFM. The framework provided a structured-decision making approach that enabled forest managers to assess vulnerability and the company's adaptive capacity, and to develop and apply adaptation options (see Figure 2.2). The four stages of the assessment include (Edwards et al., 2015):

- Phase One – Explore organizational readiness;
- Phase Two – Pre-vulnerability analysis;
- Phase Three – Detailed vulnerability analysis;
- Phase Four – Identify, implement, and monitor adaptation.

This chapter will focus on the results of the detailed vulnerability assessment (Phases One through Three), with the identification and implementation of adaptation (Phase Four) being discussed in Chapter 3.

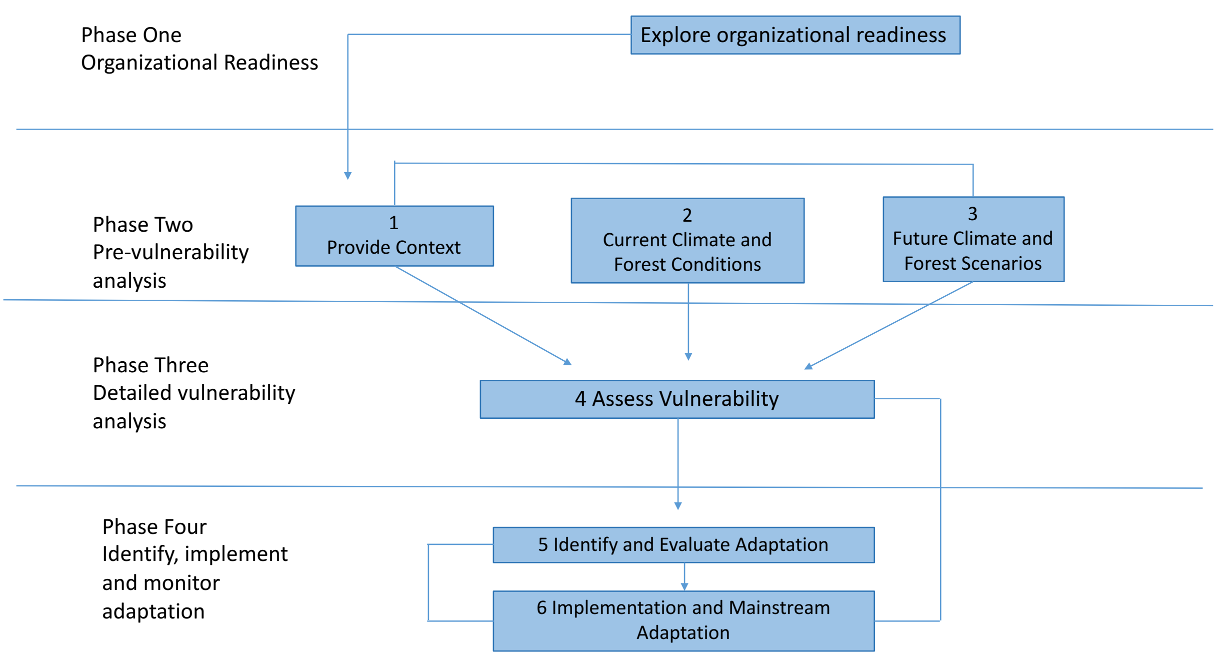

Figure 2.2 The four phases and six stages of adaptation to climate change in the context of sustainable forest management (Adapted from Williamson et al., 2012; Edwards et al., 2015).

Information for each phase was gathered from existing scientific research, Mistik's internal forest management documents, and expert knowledge of forest managers and research stakeholders. At the beginning of the case study, we established a core team for the process that consisted of senior forest managers from Mistik, and the PhD student researcher for the project. The researcher provided guidance and facilitated the process through each phase of the approach. Regular face-to-face meetings (six) and conference calls (six) were the main venues for working through the vulnerability assessment by the core team. Interviews and correspondence were carried out with other stakeholders (see Appendix C) at Mistik's Public Advisory Group meetings that are held bi-annually.

The following timeframes for climate scenarios used were (IPCC, 2014a):

- Scenario 1 Timeframe: 2010-2039
- Scenario 2 Timeframe: 2040-2069
- Scenario 3 Timeframe: 2070-2099.

The core team chose to use the worst case climate change scenario, Representative Concentration Pathway (RCP) 8.5 (IPCC, 2014a). This is considered the worst case out of all the RCPs due to the greatest degree of temperature increase to the end of the century (2100). Using this scenario allowed for the development of a variety of potential adaptation options that could accommodate a range of climate change impacts (see Appendix D).

2.3 Results

2.3.1 Phase One: Organizational Readiness

In Phase One, the company assessed its readiness for undertaking an assessment of climate change impacts on its planning and management. This phase needs to be completed before the assessment is started. In this phase, Mistik determined that their organization was ready to undertake the assessment. One of the main factors leading to this readiness was that the company had just started the renewal of their 20-year forest management plan. They had already allocated resources for the plan renewal and these could also be used for the vulnerability assessment. Also, other key factors that contributed to Mistik's organizational readiness included previous climate change work for their 2007 FMP, strong support from senior management, parent companies, the provincial government, and their Public Advisory Group (PAG), and observations regarding climate impacts from Mistik managers based on experience, knowledge and understanding (Mistik, 2016).

2.3.2 Phase Two: Pre-Vulnerability Analysis

Phase Two of the CCFM approach involved three steps:

1. Providing context for the assessment.
2. Describing and identifying current climate and forest conditions through trends, relationships between climate, forest conditions and management, and uncertainties and knowledge gaps.
3. Future climate and forest scenarios (Edwards et al., 2015).

In the first step, the forest managers determined that climate change is becoming a greater concern for SFM and is already affecting forest management and planning on Mistik's FMA (Mistik, 2015). An example of this is reduced access to sites during winter harvest due to increased frequency of freeze/thaw events. The general consensus was that climate change and climate variability would likely increase in the future, so it was time to be proactive in assessing vulnerabilities in order to address adaptive capacity and knowledge gaps. The company also determined that they needed to begin monitoring, evaluating, and developing potential adaptation options for the future. They decided that the scope of the assessment would be for the entire FMA area and this would be completed in conjunction with the FMP renewal.

Through steps two and three of the pre-vulnerability analysis, Mistik assessed climate information for the FMA that had been compiled through previous research for Mistik, climatic impacts over the past 20 years observed by senior forest managers, First Nations stakeholders within the FMA and provincial government records, and climate-related scientific research pertaining to the boreal forest in their geographic area. They decided to use RCP 8.5 to gain a stronger understanding of climate impacts, forest conditions and the dynamic relationship between them. Through the steps in Phase Two, it became evident to Mistik that the following climate-related impacts would likely be experienced on the FMA:

- Frequency and intensity of extreme weather events will increase e.g. fire and blowdown (Price et al., 2013);
- Dwarf mistletoe is already present and is expected to increase in severity with increased climatic stress (Price et al., 2013);
- Other insect and disease outbreaks are expected to increase along with the introduction of non-indigenous organisms such as mountain pine beetle. Abundance and ranges of invasive species is anticipated to increase (Price et al., 2013);
- Forest growth/mortality/productivity changes (either positive or negative) will have impacts on their Annual Allowable Cut (Price et al., 2013).;
- Regeneration success is currently excellent (98% success rate) (Mistik, 2017), however, future climate projections suggest that this may change due to limiting climatic factors, (e.g., late spring frosts, seasonal variability, drought) (Mistik, 2016);
- Land and access conditions are changing – (length of winter road season decreasing due to warmer temperatures, and earlier spring thaws); road

structures (including bridges and culverts); drainage structures; length of season when ground and water bodies are frozen – decreasing due to warmer winter temperatures, late fall freeze up and earlier spring thaw (Mistik, 2016);

- Socioeconomic conditions (including cultural factors) (Edwards et al., 2015);
- Increased beaver activity may lead to increased costs and may impede access (Mistik, 2016).

2.3.3 Gaps and Uncertainties

At the end of the pre-vulnerability phase, knowledge gaps and uncertainties became evident. Some of these included:

- Reliability and accuracy of climate modeling scenarios;
- Mistik's contractors are financially limited in their ability to purchase alternative equipment needed for salvage harvesting in blowdown stands. How is this going to be done? In addition, blowdown salvage wood is not suitable for lumber because the fibres are twisted. What are possible alternative uses?

2.3.4 Phase 3: Detailed Vulnerability Analysis

Mistik's management and planning are vulnerable to climate change. Through this assessment, Mistik has identified that under the current climate, they are able to successfully meet their SFM objectives. However, going forward, vulnerabilities are expected to increase. Using output from the RCP 8.5 scenario to establish temperature and precipitation potentials in three time periods, the experts evaluated Mistik's SFM objectives, described the known and potential vulnerabilities, and ranked the vulnerabilities according to a low-medium-high risk. Table 2.1 shows selected assessment outcomes for some representative SFM objectives. There are two SFM objectives in the table for each Criterion. In the full assessment table for all SFM objectives (Appendix A), the number of SFM objectives under each Criterion varies from two to nine.

Experts employed the assessment results to rank each of the SFM objectives according to management priorities, provincial regulations, and SFM certification requirements. The rankings were based on the number of objectives under each criterion, with one being the highest priority and decreasing. In some cases, both the vulnerability level and the priority were similar, (e.g., high vulnerability and high priority). For example, in Criterion 2: Ecosystem Condition and Productivity, the SFM objective to manage for regeneration success increases in vulnerability from climate change impacts over time, to being high in vulnerability and is also ranked as a one for priority by the forest managers, as shown in Table 2.1. However, there were also situations where the vulnerability was assessed at a higher value than its priority (see Appendix A). An example of this from Table 2.1 falls under Criterion 5: Economic and Social Benefits. The SFM objective is communities and sustainability (contribute to the sustainability of communities by providing diverse benefits from forests and by supporting local community economies) and is assessed with an increasing vulnerability over time to high, but the priority that is placed on this by the managers is a six (out of seven in total). Thus, the vulnerability assessment and the priority ranking for this SFM objective, do not correspond. In the situations where this occurs, it demonstrates that even though some SFM objectives are expected to have a high degree of vulnerability to climate change impacts moving into the future, forest managers' SFM goals and priorities may not align with the degree of vulnerability. This table has now become a tool in

Mistik's SFM and will be up-dated annually as vulnerabilities and priorities change through time.

When looking at the results for each criterion, the SFM objective impact and vulnerability, start out low and increase to medium, and high as you move further into the future under the different forest impact scenarios. It is only in Criterion 6: Society's Responsibility that the vulnerability and SFM impact are assessed as low, even under the three future scenarios. The forest managers used the results from the previous stages in phase two and three, along with their expert knowledge and experience to complete this phase of the assessment. It was also concluded, based on the results in Table 2.1, that Criteria 1, 2, and 3 (pertaining to the biological components of the SFM system) would see the greatest impacts, from climate change.

Table 2.1 Assessment and prioritization of selected SFM objectives and Mistik's adaptive capacity under current and potential future climate change.

SFM Objectives	Current Forest Condition			Forest Impact Scenario 1 (2010-2039)		Forest Impact Scenario 2 (2040-2069)		Forest Impact Scenario (2070-2099)		Prioritization ranking of SFM objectives for management and planning purposes
	SFM Objective Impact	**Adaptive Capacity**	**Vulnerability**	**SFM Objective Impact**	**Vulnerability**	**SFM Objective Impact**	**Vulnerability**	**SFM Objective Impact**	**Vulnerability**	**Ranking**
CCFM Criterion 1: Biological Diversity										
Protected Areas and sites of Special Biological Significance – Respect protected areas identified through government processes. Cooperate in broader landscape management related to protected areas and sites of special biological and cultural significance. Identify sites of special geological, biological or cultural significance within the FMA and implement strategies appropriate to their long-term maintenance.	Low	High	Low	Medium	Low	Medium	Medium	High	High	1 (there are 5 SFM objectives ranked in Criterion 1)
Species Diversity – Conserve species diversity by ensuring that habitats for the native species found in the FMA are maintained through time, including habitats for known occurrences of species at risk.	Low	High	Low	Low	Low	Medium	Medium	High	Medium/High	2
CCFM Criterion 2: Ecosystem Condition and Productivity										
Manage for regeneration success.	Low	High	Low	Low	Low	Medium	Medium	High	High	1 (there are 9 SFM Objectives ranked in Criterion 2)
Forest Growth, Mortality &/or Productivity – Productivity is directly related to Annual Allowable Cut (AAC) and is affected by changes in temperature and precipitation	Low	Medium/High	Low	Low	Low	Medium	Medium	High	High	2
CCFM Criterion 3: Soil and Water										
Water Quality and Quantity – Conserve water resources by maintaining water quality and quantity.	Low	Medium	Low	Low	Low	Medium	Medium	Medium	Medium	1 (there are 8 SFM Objectives in Criterion 3)

Soil Quality and Quantity – Conserve soil resources by maintaining soil quality and quantity.	Low	Medium/High	Low	Low	Low	Medium	Low	Medium	Medium	2
CCFM Criterion 4: Role in global ecological cycles.										
Carbon Uptake and Storage – Maintain the processes that take carbon from the atmosphere and store it in forest ecosystems.	Low	Medium	Low	Low	Low	Low/Medium	Low	Medium/High	Medium/High	1 (there are 2 SFM Objectives in Criterion 4)
Forest Land Conversion – Manage for deletions to the forest area – Protect forestlands from deforestation or conversion to non-forests, where ecologically appropriate.	Low	High/Medium	Low	Low	Low	Low	Low	Medium	Medium	2
CCFM Criterion 5: Economic and Social Benefits										
Timber and Non-Timber Benefits – Manage the forest sustainably to produce an acceptable and feasible mix of timber and non-timber forest products and forest-based services.	Low	Medium/High	Low	Medium	Medium	Medium	Medium	Medium/High	Medium	1 (there are 9 SFM objectives in Criterion 5)
Manage for sustainable non-timber resources – All commodities uses and experiences.	Low	High	Low	Low	Low	Medium	Medium	High	High	2
CCFM Criterion 6: Society's Responsibility										
Fair and Effective Decision-Making – Demonstrate that the SFM public participation process is designed and functioning to the satisfaction of the participants and that there is general public awareness of the process and its progress.	Low	High	Low	Low	Low	Low	Low	Low	Low	1 (there are 4 SFM objectives in Criterion 6)
Aboriginal and Treaty Rights – Recognize and respect Aboriginal title and rights and treaty rights. Understand and comply with current legal requirements related to Aboriginal title and rights, and treaty rights.	Low	High	Low	Low	Low	Low	Low	Low	Low	2

2.3.5 Adaptive Capacity Assessment

Mistik ranked their current overall planning and management capacity to adapt as being medium to high (see Table 2.1). The areas that were ranked as medium, or medium-to-high, were seen as areas that required additional knowledge and understanding, resources, and were not within Mistik's capacity to control or influence. The assessment highlighted that they are highly adaptable, and have existing tools that they can use for incorporating adaptation into their SFM planning and management. Some of these tools include their ISO 14001 Environmental Management System and internal Standard Operating Procedures. At the end of Phase Three, a decision was required to determine whether they needed to continue to Phase Four of the vulnerability assessment. In this phase they would identify, implement, and monitor adaptation. Based on the outcome of Phases One through Three, there was enough evidence to suggest that adaptation is required to cope with climate variability and potential climate impacts. The results of Phases One through Three demonstrate that Mistik's SFM system is vulnerable to climate change now and into the future. It is also evident that they expect current vulnerabilities to increase and new vulnerabilities to emerge. Continued monitoring and reassessment is essential to the future success of Mistik's planning and management because it will enable practitioners and policy analysts to adjust their approach and adaptation mainstreaming. The results of undertaking Phase Four of the assessment is the subject of Chapter 3.

2.4 Discussion/Conclusion

Through Phases One, Two and Three of the CCFM approach, key lessons were learned by the forest managers involved in this process. These included:

- The organization doing the vulnerability assessment needs to be intimately involved in the assessment so they “own it”. There is no one better than the local forest managers to assess their own SFM system by applying the CCFM framework.
- Many of the tools and foundational pieces needed to complete this assessment are already part of forest planning and management.
- Developing a strong network of researchers, managers and stakeholders that will be involved throughout different stages of the vulnerability assessment will help in ensuring that the assessment has real-world applicability.
- Having a solid communications plan with defined roles and expectations is crucial during the vulnerability assessment. This will also help ensure that “everyone is on the same page” as the assessment evolves. It is also important to revisit the outcomes defined during Phase One, so the assessment team does not lose sight of what they are assessing.

The results of Phases One through Three demonstrate that Mistik’s SFM system is vulnerable to climate change now and into the future. It is also evident that they expect vulnerabilities to increase. Continued reassessment and monitoring is essential to the future success of Mistik’s planning and management.

The results of this research are being used by both Mistik Management Ltd. and the Saskatchewan Provincial Government. Mistik has already integrated the detailed vulnerability assessment table into their SFM as a tool for monitoring their SFM objectives’ vulnerabilities and priorities on an annual basis. Using this as a monitoring tool will enhance the forest managers’ ability to increase their adaptive capacity and address vulnerabilities as things change in their system as a result of climate change impacts. The provincial government is using the information gathered in the assessment to help guide future research and policy direction to provide support to SFM practices and planning to address climate change impacts.

Forest planning and management is vulnerable to the effects of climate change (Parry et al., 2007). It is also evident that future vulnerabilities will increase in magnitude. Even though vulnerabilities for most SFM objectives are currently low, continued reassessment will increase the forest manager's ability to proactively mainstream adaptation into forest planning and management programs (Halofsky et al., 2011b). Given current climate, and climate variability, as well as expected future climate change impacts, forest managers will be challenged by reduced responsiveness and flexibility of policy, low levels of adaptive capacity, societal values, economic constraints, or lack of locally relevant research (IUFRO, 2009). The biophysical elements and the management of the boreal forest are both vulnerable to climate change. The combination of biophysical and institutional elements makes assessing climate change impacts and managing within SFM systems difficult for forest managers (Williamson et al., 2009). The CCFM vulnerability assessment tools and techniques provide a systematic approach designed to help practitioners implement and adjust more resilient responses than would be otherwise possible and potentially enhance adaptive capacity and management.

Climate change will present many challenges and some opportunities for forest managers around the world and there are differences in how planning and management is undertaken in different locations (IUFRO, 2009). Clearly, the uncertainties associated with predicting climatic impacts and variability can be a daunting task for forest managers (Mistik, 2015). The results of the research done in this project demonstrate that the CCFM approach provides a strategic step-by-step process that can be applied to SFM at the FMA level by forest managers. Through the application of this framework, forest managers across Canada can tailor the approach to their local SFM goals and objectives. Any organization that wants to increase their understanding, adaptive capacity, and resilience for climate change impacts can follow this systematic approach (Gray, 2012). Even though our case study was completed by forest managers in Saskatchewan, the structure and content of the approach is transferable to any level and complexity of SFM planning and management. As climate change impacts on the boreal forest and associated planning and management increases, it is going to become more important for managers to make use of tools that will aid in adapting to these impacts.

PREFACE TO CHAPTER 3: ADAPTATION IN SUSTAINABLE FOREST MANAGEMENT: CASE STUDY WITH MISTIK MANAGEMENT LTD.

The second objective of this thesis was to assist forest managers in developing potential adaptation options for climate change along with tools for evaluating, monitoring, implementing and mainstreaming adaptation into sustainable forest management practices in the forest sector. Chapter 3 focuses on the mainstreaming of adaptation in the context of sustainable forest management. Identification of adaptation options and tools for mainstreaming them into existing forest management were developed through a case study with a forest company in Canada. The approach was based on a strategic step-by-step process for assessing climate change vulnerability and adaptation mainstreaming developed by the Canadian Council of Forest Ministers (CCFM). It was applied at the Forest Management Area (FMA) scale with a forest industry partner. This was the first example of adaptation mainstreaming in a SFM system at the FMA level completed in Canada. We found that tools already exist in SFM systems that enable the mainstreaming of adaptation to climate change in forest management and planning. Challenges and barriers to potential long-term adaptation options were also assessed and discussed, providing direction for managing forests sustainably with increasing uncertainty and risk.

CHAPTER 3: ADAPTATION IN SUSTAINABLE FOREST MANAGEMENT: CASE STUDY WITH MISTIK MANAGEMENT LTD.

3.1 Introduction

Forest ecosystems are complex and are expected to be affected by climate change impacts (IUFRO, 2009). The health and sustainability of Canada's boreal forests are vulnerable to climate change (Ohlson et al., 2005). It is also likely that sustainable forest management objectives may be harder to achieve in the future in the face of climate change (Swanston and Janowiak, 2012). In order to maintain and enhance the long-term health of forest ecosystems, scientists, forest managers, and policy makers have been investigating the effects that a changing climate will have on the current and future sustainability of the boreal forest (Gray, 2012). The task confronting forest managers and policy makers is to develop adaptation options that can be mainstreamed into all aspects of existing sustainable forest management (SFM) systems and policy (CCFM, 2008).

Mainstreaming adaptation will present both challenges and opportunities in forest management, planning and policy (Edwards and Hirsch, 2012). Many approaches for adaptation start with completing a climate change vulnerability assessment. There are many examples of climate change vulnerability assessments that have been completed for forest ecosystems in North America and Europe (Lindner et al., 2010; Halofsky and Peterson, 2018). However, moving to adaptation mainstreaming still remains in the early stages of application (Halofsky et al., 2018). Embedding climate change adaptation into all aspects of SFM will require the use of existing tools (Spittlehouse, 2005) and new tools and techniques that are developed along the way. SFM planning and practices are based on a structured set of objectives that allow for the mainstreaming of adaptation (Edwards and Hirsch, 2012). Through the use of these existing policies and practices, mainstreaming adaptation can flow to all elements of sustainable forest management (Edwards et al., 2015).

The development of science-management-policy partnerships is also important in mainstreaming adaptation (Williamson et al., 2012). Through mainstreaming, adaptation options become embedded into all aspects of SFM from policy to practice (Edwards and Hirsh, 2012). As such, it is important that adaptation is based on science and can be applied to management and translated into policy (Spittlehouse and Steward, 2003). In the science-management-policy partnership, more advanced tools for adaptation and mainstreaming can be developed, and knowledge exchange will be increased (Williamson et al., 2009). This will strengthen mainstreaming of adaptation into existing forest planning, management, and policy.

In this chapter we describe a case study that included mainstreaming adaptation into an existing SFM system in Saskatchewan, Canada. This is the first example of its kind in which a forest company has moved beyond an initial climate change vulnerability assessment, to incorporate climate change adaptation into their existing forest management and planning at the FMA level. Using the CCFM approach to adaptation mainstreaming, Mistik Management Ltd., a forest company located in Meadow Lake, Saskatchewan (Figure 3.1), identified its vulnerability to climate change. The forest managers were then able to identify and implement adaptation for their SFM planning and practices. The results of this work demonstrate that mainstreaming of adaptation into existing forest management and planning at the FMA level can be successful using the CCFM approach.

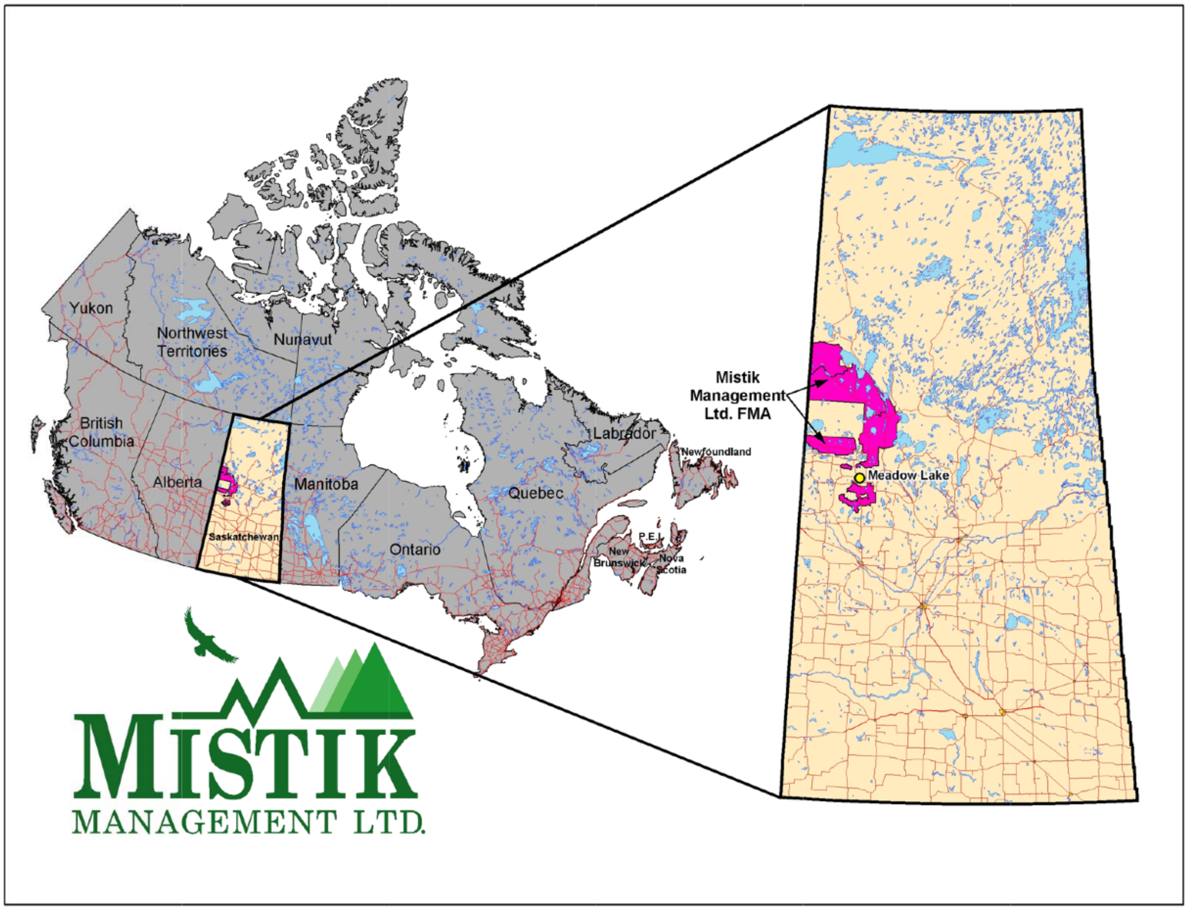

Figure 3.1 Map of Mistik Management Ltd. FMA location in Saskatchewan, Canada (Mistik, 2007).

The process of identifying and assessing vulnerabilities of forest ecosystems and SFM systems are presented in Chapter 2. The governance and policy implications, and challenges and barriers of mainstreaming adaptation, are presented in Chapter 4.

3.2 Approach

The methodology used in this research follows the CCFM approach for adaptation mainstreaming in order to test the approach at the FMA level (Edwards et al., 2015). The first three phases of the approach focused on completion of a vulnerability assessment for the SFM system in the case study (Figure 3.2). For this case study, the forest managers concluded that adaptation was required and moved forward to adaptation mainstreaming. This chapter focuses on Phase Four which involves mainstreaming of adaptation and the methods of identifying, implementing, and monitoring adaptation within an SFM system.

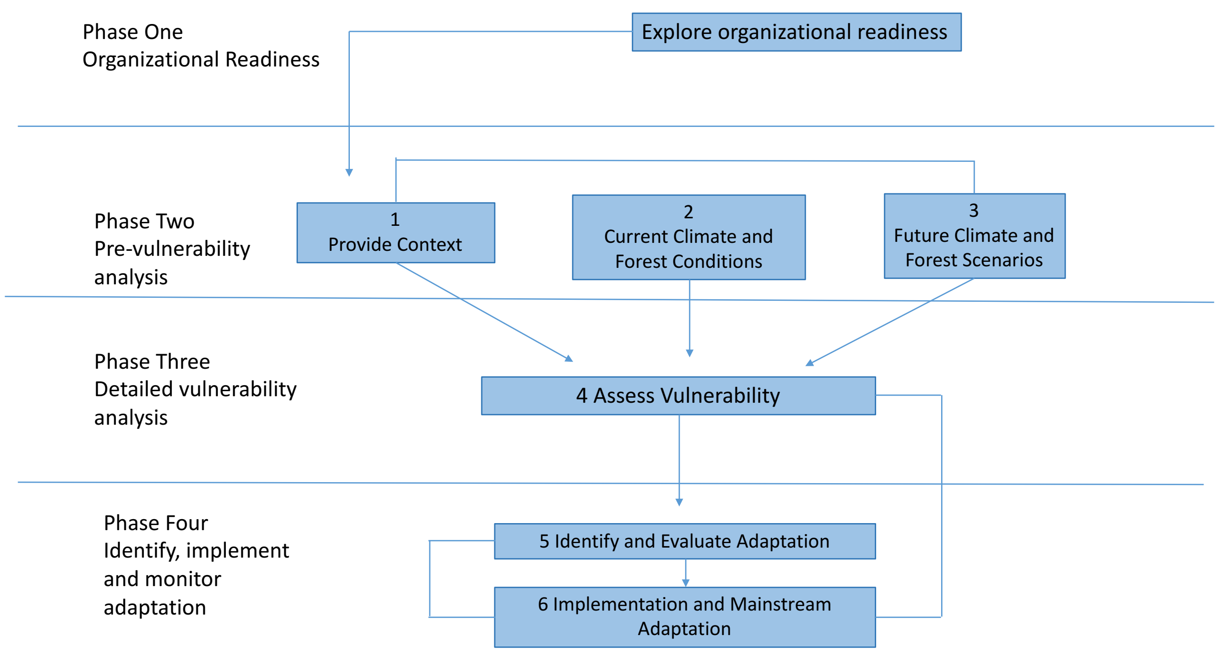

Figure 3.2 The four phases and six stages of adaptation to climate change in the context of sustainable forest management (Adapted from Williamson et al., 2012; Edwards et al., 2015).

The final phase of the CCFM approach has two stages (Figure 3.2):

- Identify and evaluate adaptation options, and
- Mainstream adaptation (Edwards et al., 2015).

First, we developed potential adaptation options for Mistik's SFM objectives. We worked with senior forest managers to review the adaptation options provided in the inventory of potential adaptation options in the CCFM guidebook (Edwards et al., 2015). The inventory provided a science and management-based starting point for considering potential adaptation options. Based on Mistik's SFM system and their policy environment, the forest managers assessed, modified, and ranked potential adaptations for each of the CCFM SFM Criteria. The CCFM SFM Criteria and Indicators (C&I) are a national framework for assessing the achievement of sustainable forest management, and are based on the international set of C&I developed under the Montreal Process (Montreal Process, 2015). There are six Criteria on which Mistik bases their SFM system. Using the inventory from the CCFM Guidebook as a starting point, the core study team modified and added to the list.

The core team then prioritized the adaptation options and recommended some for immediate implementation. Adaptation options were mainstreamed (see Table 3.1) and the forest managers determined evaluation strategies for adaptation performance. Mistik's senior managers mainstreamed the adaptation options by integrating them into their forest management plan, operational plans, and internal Standard Operation Procedures. The case study commenced at the onset of Mistik's strategic forest management plan renewal, which provided an opportune time to undertake a climate change vulnerability assessment and adaptation mainstreaming.

3.3 Results

The results in this chapter focus on the outcomes from the final phase of the CCFM approach. A sample of the modified inventory of adaptation options is shown in Table 3.1. (The full table is in Appendix B). The options shown in Table 3.1 provide examples of both strategic and operational adaptation options for each of the CCFM SFM Criteria.

Table 3.1 Inventory of Potential Adaptation Options

CCFM SFM Criterion	***Climate Change Impact/Vulnerability***	***Forest Management Planning Level***	***Adaptation Options***	***Feasibility Ranking*** 1- Desirable/Doable 2- Possible but harder to accomplish 3- Greater difficulty for feasibility and implementation 4- Not Feasible	***Potential Challenges/Barriers/ Recommendations***
Biological diversity	Alteration of plant and animal distribution	Strategic	Develop a gene management program to maintain diverse gene pools	4	Financial barriers - Millions of $$$ needed; needs to be national/provincial initiative; very specific research. Regulation barriers: Mistik must use local seed source according to prov. SFM policy/regs
Biological diversity	Increased frequency and severity of forest disturbance	Operational	Allow forests to regenerate naturally following disturbance wherever appropriate	1	
Ecosystem condition and productivity	Increased frequency and severity of insect and disease disturbance	Strategic	Adjust harvest schedules to harvest stands most vulnerable to insect outbreaks	2-3	Depends on the scale across the land base – at this point a main barrier/challenge is that there is too much uncertainty from a forest manager's perspective.
Ecosystem condition and productivity	Increased frequency and severity of insect and disease disturbance	Operational	Breed for pest resistance and for a wider tolerance to a range of climate stresses and extremes in specific genotypes	4	Policy/regulation constraints Financial barriers Beyond our ability as a company Look to Federal & Provincial government for a research initiative
CCFM SFM Criterion	***Climate Change Impact/Vulnerability***	***Forest Management Planning Level***	***Adaptation Options***	***Feasibility Ranking*** 1- Desirable/Doable 2- Possible but harder to accomplish 3- Greater difficulty for feasibility and implementation 4- Not Feasible	***Potential Challenges/Barriers/ Recommendations***
Soil and Water	More/earlier snow melt resulting in changes in the timing of peak flow and volume in streams	Strategic	Re-assess river and stream peak flows and link this information to design standards for	1	

			bridges and roads		
Soil and Water	More/earlier snow melt resulting in changes in the timing of peak flow and volume in streams	Operational	Examine the suitability of current road construction standards and stream crossings to ensure they adequately mitigate potential impacts on infrastructure, fish, and potable water of changes in timing and volume of peak flows	1	
Role in global ecological cycles	Decrease in forest sinks and increased CO_2 emissions from forested ecosystems because of increased frequency and severity of forest disturbance	Strategic	Identify forested areas that can be managed to enhance carbon uptake	2	
Role in global ecological cycles	Decrease in forest sinks and increased CO_2 emissions from forested ecosystems due to declining forest growth and productivity	Operational	Enhance forest growth and carbon sequestration through fertilization	3	Financial challenges – not good investment; impractical (e.g. Based on past experiences)
CCFM SFM Criterion	***Climate Change Impact/Vulnerability***	***Forest Management Planning Level***	***Adaptation Options***	***Feasibility Ranking*** ***1- Desirable/Doable*** ***2- Possible but harder to accomplish*** ***3- Greater difficulty for feasibility and implementation*** ***4- Not Feasible***	***Potential Challenges/Barriers/ Recommendations***
Economic and social benefits	Decreased socio-economic resilience	Strategic	Diversify regional economy (lessen the dependence on the forest)	4	Provincial government role (policy/regulation challenges) Many of the non-timber industries are very cyclic as well (e.g. wild rice harvesting)
Economic and social benefits	Decreased socio-economic resilience	Operational	Develop technology to use wood of altered quality and to use different tree species, modify wood processing technology	4	Financial and equipment challenges

Society's responsibility	Forest management plans and policies lack the flexibility that is required to respond to climate change	Strategic	Evaluate the adequacy of existing environmental and biological monitoring networks for tracking the impacts of climate change on forest ecosystems, identify inadequacies and gaps in these networks and identify options to address them	4	Federal/Provincial initiative required Long-term monitoring needed both regionally/nationally Mistik is currently practicing this on a small scale on FMA and through research with undertaking a Climate Change Vulnerability Assessment and working on adaptation options, tools and mainstreaming.
Society's responsibility	Decreased socio-economic resilience	Operational	Incorporate new knowledge about the future climate and forest vulnerability into forest management plans and policies	1	Mistik has done this through using the CCFM approach to adaptation (For the policies piece – Mistik is providing suggestions and feedback to the provincial government to aid in policy responsiveness and flexibility for climate change adaptation)

(Adapted from the CCFM Framework, Edwards et al., 2015).

Each adaptation option is categorized by the following:

- CCFM SFM Criterion to which it applies,
- The type of vulnerability caused by climate change,
- Whether the option is strategic or operational in planning and management,
- A feasibility ranking, based on the forest manager's understanding of how easily the adaptation option could be mainstreamed,
- Challenges/barriers and recommendations for some of the adaptation options.

Potential adaptation options with a rank of 'one' or 'two' denote few if any barriers and are strong candidates for implementation and mainstreaming. An example illustrating this would be under the CCFM SFM Criterion – Biological diversity. The climate change vulnerability or impact is ‘increased frequency and severity of forest disturbance’ and is at the operational forest management planning level. The adaptation option is designed to allow for natural regeneration following disturbance wherever possible. The feasibility ranking of implementing this adaptation option currently into Mistik’s SFM is ‘one’, which is both desirable and doable by the forest managers. Many of the options ranked as ‘one’ are already part of Mistik’s SFM planning and practices. The options ranked ‘three’ and ‘four’ were seen as having significant challenges and barriers for mainstreaming by the forest managers. An example of an adaptation option ranked as a ‘four’ (not feasible) is under CCFM SFM Criterion – Economic and social benefits. The climate change vulnerability or impacts is decreased socio-economic resilience. The adaptation option is at the operational forest management planning level and is to develop technology to use wood of altered quality and to use different tree species, and to modify wood processing technology. The potential challenges or barriers that the managers identified involved financial and equipment challenges.

The challenges, barriers and recommendations are presented in a separate column in the inventory table. In the challenges/barriers/recommendations assessment, some of the re-occurring themes included (see full Table in Appendix B):

- Policy/regulations challenges/barriers,
- Knowledge and information gaps,
- Financial challenges/barriers,
- Certification challenges,
- Equipment/technology challenges.

We found that Phase Four of the CCFM approach was easily applied at the spatial and temporal scales of Mistik’s FMA and SFM system. The inventory of adaptation options served as a logical starting point for adaptation identification and development that fit in their forest management and planning (Mistik, 2017). The inventory of adaptation options is a “living” document that is now mainstreamed into Mistik’s SFM system, subject to review and revision, as needed on an annual basis. Some of the adaptation options that have significant challenges and barriers and are not ranked as being very feasible currently (i.e., 3 or 4), may become more feasible in the future as the challenges and barriers are overcome or priorities, management, or policies change. Some of the adaptations are not specifically practical for Mistik’s FMA, but may be more suitable in other regions across Canada and under different forest management goals and objectives.

In the final stage of mainstreaming adaptation, the forest managers determined how to incorporate adaptation into Mistik’s existing SFM system. They used the following mainstreaming criteria, as outlined in the CCFM approach (Edwards et al., 2015):

- Assessed the jurisdiction within which the adaptation actions fall and the roles and responsibilities of various agencies and individuals in implementation.
- Identified the actions required to implement the adaptation (e.g., changes in planning, procedures, policies, regulations, legislation, investments, protocols, guidelines, training, and operational methods).
- Identified opportunities to mainstream the adaptation into day-to-day processes.
- Assessed the internal and external support required for implementation to proceed.
- Identified human, financial, and information/technological resources required for implementation.
- Identified schedules associated with implementation.
- Determined communication strategies for implementation, (staff, other stakeholders).
- Determined what tools would be used for monitoring and evaluation of adaptation.

At this point, it was important to determine what tools and mechanisms were necessary to enable the mainstreaming of adaptations into the SFM system. This included incorporating adaptations into strategic long-term planning and into day-to-day operations (Edwards et al., 2015). In the Mistik case study, the forest managers determined that they already had the key tools necessary to begin mainstreaming adaptation. The tools included:

- Internal Standard Operating Procedures (SOPs),
- ISO 14001 Environment Management System (EMS) standard,
- Annual Report,
- Forest Management Plan (FMP) (Required by the provincial government).

All of these tools are already part of Mistik's SFM system, and using the CCFM approach, they determined that mainstreaming of climate change adaptations fit easily into these procedures.

Mistik has 21 internal SOPs that are part of their EMS system. They are written procedures that ensure forest management activities are performed in an effective and compliant manner that follow provincially regulated standards and guidelines in an environmentally responsible way. Each of the SOPs was assessed as part of the vulnerability assessment. Of the 21 SOPs, it was determined that seven SOPs would be adapted to include a climate change element, as they were seen as pertaining to elements of Mistik's SFM system that were most sensitive to climate change impacts through the vulnerability assessment:

- Soil Protection: This procedure describes the criteria to be met to minimize the impact of forest soil disturbance caused by forestry operations. This procedure applies to all Mistik-related roads and harvest blocks on the Mistik FMA area.
- High Conservation Value Areas Effectiveness Monitoring: High Conservation Value Forests (HCVF) are defined by the Forest Stewardship Council (FSC) as forests that possess one or more attributes that are outlined in this SOP. Mistik has considered a

broad range of values and has a lengthy list of designated High Conservation Values (HCVs). The HCVs are expected to be affected by climate change to varying degrees over time.

- Self-Inspection and Reporting: This procedure describes the process for self-inspection pertaining to Mistik's operational standard operation procedures. This procedure applies to Mistik as an organization and the Mistik FMA Area (e.g., annual inspection on roads and watercourse crossings).
- High Conservation Value Areas Planning and Forestry Implementation: This procedure describes the process that is to be followed when planning and conducting forestry activities in areas identified as HCVAs.
- SFM Indicator Monitoring and Reporting: This procedure describes the process for the monitoring of SFM indicators and the reporting procedure to senior management and Mistik's Public Advisory Group. Mistik shall establish procedures that shall be reviewed annually and, if required, updated, so that monitoring and reporting of Mistik's SFM indicators are effectively conducted.
- Pre-Harvest Site Prescription: This procedure describes the criteria to be met to ensure that appropriate operational forest harvesting activities are prescribed, prior to harvest, for implementation in approved locations so that forest harvesting impacts on the environment are minimized.
- Road and Harvest Block Layout: This procedure describes the criteria to be met to ensure forest harvesting activities occur in approved locations so that forest harvesting impacts on the environment are minimized. This procedure applies to all Mistik-related roads and harvest blocks on the Mistik FMA area (Mistik, 2018).

The SOPs include monitoring, evaluating, and prioritizing elements directly and indirectly related to climate change impacts occurring within Mistik's SFM system. By incorporating a climate change element into each one of the SOPs identified above, Mistik will be able to monitor and evaluate climate change impacts occurring on the ground, on an ongoing basis. It will also provide a record of the impacts on an annual basis for future planning and adaptation development. The SOPs are annually reviewed and modified as needed, through the company's Environmental Monitoring System standard. Information that is gathered through the SOPs will also be integrated into the annual report.

Mistik's annual report is another tool identified as part of their adaptation mainstreaming process. They have included a climate change vulnerability and adaptation section in the report that includes a detailed table of all of their SFM objectives and indicators and includes the climate related vulnerabilities for each. Also included are the priority rankings of each, along with any additional climate change adaptations implemented and their effectiveness. The annual report will also serve as a means of compiling and reporting on climate change impacts on the FMA.

The Forest Management Plan is another tool that forest managers recognized as being useful for adaptation mainstreaming. FMPs are required by Saskatchewan legislation and provide strategic-level direction for management of forest resources within a Forest Management Agreement (FMA) area. The FMP establishes goals, objectives, and strategies to guide forest management activities, describes desired future forest conditions, and seeks to address land and resource use issues (Mistik, 2018). In Mistik's current FMP renewal, they are including a climate change section that will include their SFM vulnerabilities and adaptation mainstreaming, which ties into their SFM goals, objectives, and strategies in their SFM system.

3.4 Discussion - Implementation and Mainstreaming of Adaptation

This research has demonstrated that the CCFM approach can be successfully used as a tool for mainstreaming adaptation into existing sustainable forest management systems (Mistik, 2017). By following the strategic step-by-step process provided in the approach, forest managers were able to embed adaptation options at both strategic and operational levels of their SFM system (Inns et al., 2009). To the authors' knowledge, this effort is the first of its kind to be completed at the FMA level by forest managers in Canada using the CCFM approach.

During the case study, the forest managers highlighted the following advantages to using the CCFM approach for mainstreaming adaptation:

- The generic approach of the CCFM framework made it easy to apply to their SFM system,
- Strong science-management components of each phase fit well with SFM goals and objectives of the organization,
- Logical sequence of phases made it user-friendly,
- The worksheets used for compiling information for each stage were well designed and helpful,
- Foundational theory and methodology of the CCFM approach follows the guiding principles of the SFM C&I in Canada, which also aligns with forest management certification standards,
- The approach helped managers identify existing tools in their SFM system for use in monitoring, mainstreaming, and evaluating adaptation for day-to-day operations and long-term strategic planning,
- Managers were able to apply the CCFM approach internally, without hiring consultants to complete the work,

- The CCFM approach helped to increase the organization's adaptive capacity and provided guidance in mainstreaming climate change into all aspects of their SFM system (Mistik, 2018).

Overall, the managers were very positive regarding the structure, methodology, and process of the CCFM approach. As other forest managers apply the approach, they will adapt and tailor it to fit their needs and the SFM system they are assessing. The flexibility of the CCFM approach lends itself well to this (Mistik, 2018).

The process of using the CCFM approach to mainstream adaptation has provided value to Mistik by increasing their overall adaptive capacity, helping them to understand and prioritize climate change vulnerabilities, identify gaps and needs for adaptation, and develop adaption options. The case study provided a foundation for guidance for other forest managers and governments to move towards developing collaborative approaches needed for both management and policy adaptation and mainstreaming (Halofsky et al., 2018). The results from this case study also increased the state of knowledge and understanding on adaptation mainstreaming within sustainable forest management in Canada.

3.5 Conclusions

As the forest management community advances in climate change science, they will also be able to advance and improve adaptation mainstreaming into SFM systems and policy (IUFRO, 2009). Climate change vulnerability assessments are taking place at various scales and within different sectors on national and international levels (IPCC, 2007b). As more assessments are completed, they will provide practical on-the-ground examples to help increase the knowledge and understanding of mainstreaming adaptation in the forest sector (Edwards and Hirsch, 2012). This will increase the ability of forest managers to manage forest ecosystems more sustainably (Spittlehouse, 2005).

Sharing of knowledge, increased collaboration, and coordination between scientists, forest managers, government, and other stakeholders have significant benefits for forest ecosystems and their management (Gitay et al., 2001; Halofsky et al., 2018). Through increased collaboration, there is also the opportunity for greater communication, dissemination of information, increased understanding and knowledge transfer to aid in steps towards mainstreaming of adaptation. It also provides a network for the different groups and agencies involved in forest management for continuous learning and a method for accessing valuable insights into how forest management practitioners use information to support adaptation decision making (Halofsky et al., 2018).

Some of the challenges and barriers to mainstreaming can be seen as insurmountable obstacles to the incorporation of adaptations into SFM systems (Edwards et al., 2015). Implementation may require a change in the way of doing business, such as changes in planning, procedures, policies, regulations, legislation, investments, protocols, guidelines, training, and operational methods (Williamson et al., 2012). By identifying these challenges and barriers, the adaptive capacity of those involved will increase and will provide the opportunity to work towards solutions for effective mainstreaming of adaptation (Williamson et al., 2012). Facilitating adaptation through science-management-policy partnerships is one of the key elements to accomplish adaptation development and mainstreaming. Mainstreaming of sound adaptation options, supported by science, is an integral component of the development of SFM in an uncertain and changing future (Edwards et al., 2015).

PREFACE TO CHAPTER 4: GOVERNANCE AND POLICY: ADAPTATION TO CLIMATE CHANGE IN SUSTAINBLE FOREST MANAGEMENT IN SASKATCHEWAN

Chapter 4 addressed the governance and policy aspects of this thesis. It presents evidence for the importance of a more collaborative approach to policy making in order to mainstream adaptation into contemporary forest policy as recommended by the Canadian Council of Forest Ministers (CCFM) framework. In Canada, the CCFM framework is the core instrument for assessing vulnerability and adaptive capacity, and mainstreaming adaptation into sustainable forest management (SFM). The framework has been applied in a case study with forest industry in Saskatchewan, Canada and helps to address building responsiveness and flexibility into existing forest policy (IUFRO, 2009).

This chapter identifies the roles of Mistik Management Ltd. and the Forest Service Branch of Saskatchewan Environment in the case study. It also discusses how government and industry have collaborated throughout the project, and how the results of the research will assist policy makers in incorporating greater responsiveness and flexibility into sustainable forest management policy and regulations. Also discussed is how this collaboration has increased the adaptive capacity of the government so that it will be better equipped to address climate change and SFM, and some suggestions for doing this. Barriers and challenges for government and practitioners are discussed and future directions are suggested.

CHAPTER 4: GOVERNANCE AND POLICY: ADAPTATION TO CLIMATE CHANGE IN SUSTAINBLE FOREST MANAGEMENT IN SASKATCHEWAN

4.1 Introduction

Forests are being affected by direct and indirect impacts of climate change, on both global and local scales (IUFRO, 2009). Contemporary forests are complex socio-ecological systems, where biological and social elements combine to influence outcomes. In Canada, governments, industry, First Nations, and many other stakeholders all place different value and significance on forests, making the sustainable management of forests very complex (Edwards et al., 2015). Nevertheless, it is widely accepted that the challenge of complexity can be met such that sustainable forest management measures for climate change adaptation can be supported by appropriate policy means that respect the complex values and resources that forests provide (IUFRO, 2009). To do so, policies and management practices will need to be less prescriptive and more flexible to enable "forest managers to respond adequately to the local conditions of the forest site, to accommodate indigenous knowledge and to consider the needs of local people regarding the provision of forest goods and services" (IUFRO, 2009).

The challenge of how to continue managing forests sustainably in the face of climate change is not unique. Its salient features mirror those in many other contemporary policy areas and for exactly the same reasons: expansion of the goals of policy, largely driven by the recognition of the legitimate claims of new groups and interests to be included in the policy process; uncertainty about the most effective policy interventions to achieve these goals because of rapid change in complex socio-ecological systems; and the suggestion that a solution can be found by giving front-line managers more "flexibility" to respond to a rapidly-changing implementation environment. Seen in this light, the original challenge can be decomposed into three distinct but related challenges. The governance challenge is to create a viable and trustworthy process for making decisions about policy objectives with so many new actors involved; the policy design challenge is to ensure that the governance process results in policies that are mutually coherent and consistent; and the implementation challenge is to reconcile flexible implementation with both stable policy and legitimate and effective governance.

This chapter breaks new ground by presenting this set of nested “governance-policy-management” challenges from the perspective of forest managers themselves. In December 2014, the Ministry of Environment, Forest Service Branch in Saskatchewan, Canada, held a workshop to explore different climate change impacts and potential climate scenarios within the forests of Saskatchewan. The participants discussed the uncertainty surrounding the effects of climate change and future direction for addressing this uncertainty. Forest managers and policy makers from the private and public sector participated in this workshop. Suggestions for the government on how to proceed from here with respect to guiding future policy, surrounding climate change were also discussed. One of the main outcomes from this workshop was that there needed to be something done to aid forest managers in addressing adaptation to climatic uncertainty, but no one had any idea of where to begin. By identifying this gap in capacity for the province and forest managers to address these issues, the provincial government took the initiative to collaborate with forest managers. Through this initiative, we included a case study for developing low-risk, feasible, applicable, and practical adaptation options to help forest management practitioners mainstream (or integrate) climate change adaptation into sustainable forest management (SFM) practices. Primary questions explored included:

- What vulnerabilities are forest managers facing with respect to climate change impacts within their SFM systems?
- What potential adaptation options can be developed and mainstreamed into SFM planning and what tools will be utilized to enable this?

- What steps can be taken to ensure that policy will be responsive and flexible enough to ensure capacity to adapt to climatic uncertainty within a reasonable time frame?

While the first two questions and outcomes are considered in chapters 2 and 3, the third question about responsive and flexible policy is the focus of this chapter. In terms of the three challenges identified above, this chapter highlights the importance of a competent and collaborative governance system designed to constantly address the knowledge and policy gaps that may limit adaptive capacity going forward.

In Saskatchewan, as in many other jurisdictions, forest policy strives to reconcile these two objectives by means of a results-based approach to regulation and forest management. The results-based approach is presented as a credible response to address the uncertainties of climate change and adaptation within a broader policy framework of sustainable forest management. Using the results of the case study, the province will be able to apply the results-based approach to integrate adaptation, flexibility, increased communication and responsiveness into policy. The results of this case study will also be utilized for helping guide and shape future research initiatives, and policy modification or development, where necessary.

For policy development at a provincial level in Canada, integration of climate change impacts and adaptation will promote increased resilience and adaptive capacity for forest managers and policy makers to practice SFM in the face of climatic uncertainty. It will also provide the opportunity to build these key elements into the governance structure and promote a new direction for governance (IUFRO, 2009).

4.2 Forest Policy

In Canada, the role of the federal, provincial, and territorial governments varies in terms of policy direction, development, and enforcement within forestry. SFM is the predominant forest policy paradigm that guides forest management and policy on a national, provincial, and territorial level within Canada. SFM, as defined by the CCFM, is "management that maintains and enhances the long-term health of forest ecosystems for the benefit of all living things while providing environmental, economic, social, and cultural opportunities for present and future generations" (CCFM, 2008). According to the CCFM, "the criteria for defining and monitoring sustainable forest management in Canada are biodiversity, ecosystem condition and productivity, soil and water, role of forests in global ecological cycles, economic and social benefits, and society's responsibility" (Edwards et al., 2015). The CCFM is a partnership between Canada's federal, provincial and territorial governments that endorses the principles of sustainable forest management and has been in place since 1992 (CCFM, 2008). "The provinces and territories, which hold jurisdiction over nearly all of the country's forest land, work to ensure sustainable forest management standards are met. These efforts are well supported by laws, regulations and polices, a rigorous forest management planning process, and a science-based approach to decision-making, assessment and planning" (CCFM, 2008).

Approximately 93% of forest land in Canada is owned by the crown (CCFM, 2008). Forest tenure agreements are established with private-sector forest companies that allow them to harvest certain timber volumes on crown land (CCFM, 2008). In most provinces across Canada, the larger tenure agreements are renewed on a 20-25-year period. The companies must adhere to the provincial forest management policies and regulations for SFM to ensure that all the resources within the assigned tenure, are managed sustainably.

In Saskatchewan, crown forests are managed under the guiding principles of SFM developed by the CCFM. Saskatchewan's forest management policy framework is set out in *The Forest Resources Management Act*. From this, the Forest Service Branch in Saskatchewan has "developed a framework of values, objectives, indicators and targets (VOITs) to be utilized as a basis for forest management" (Province of Saskatchewan, 1996). "The VOITs have been established as a standard requirement for Crown forest lands in Saskatchewan" (Province of Saskatchewan, 1996).

Forest certification also plays an important role in the management and economic well-being of the forest industry. Canada has the largest certified forest area in the world, with 170 million ha being certified (NRCAN, 2018). There are three certification systems in Canada:

- Canadian Standards Association (CSA)
- Forest Stewardship Council (FSC)
- Sustainable Forestry Initiative (SFI)

Certification provides an independent, third-party SFM standard that offers added assurance forests are being managed sustainably (NRCAN, 2018). Certification standards are based on SFM principles and are regularly being reviewed and revised to keep pace with new science and innovation. However, currently, no certification scheme has developed specific standards that directly address climate change and accounting for it within.

4.3 Methodology

This chapter uses qualitative methods. Policy development, forest planning and implementation are initially assessed against the blueprint set out in the *CCFM Climate Change and Sustainable Forest Management in Canada: A guidebook for Assessing Vulnerability and Mainstreaming Adaptation into Decision Making,* which is a framework for assessing vulnerability and adaptive capacity to climate change within a SFM system, and then providing steps to develop adaptation options and mainstreaming (Edwards et al, 2015). "The framework, which provides a structured decision-making approach to adapting SFM to climate change", (Edwards et al., 2015) is comprised of four phases (Figure 4.1):

- Phase One – Organizational readiness: The aim of Phase One is to explore the organization's readiness to undertake an SFM vulnerability and adaptation assessment. This guidebook assumes that this single stage has been completed and that the organization is prepared to initiate a SFM vulnerability assessment and potentially to change SFM policies and practices, if required.
- Phase Two – Pre-vulnerability analysis: The aim of Phase Two is to develop the context of the assessment, describe the current climate-forest relationships, and develop future climate and forest impact scenarios.
- Phase Three – Detailed vulnerability analysis: The aim of Phase Three is to identify where SFM is vulnerable to climate change (and therefore where adaptation is needed) and where opportunities or positive effects could occur (which could be enhanced by adaptation).
- Phase Four – Identify, implement, and monitor adaptation: The aim of Phase Four is to evaluate, implement, monitor, and mainstream adaptation measures into SFM decision making (Edwards et al., 2015).

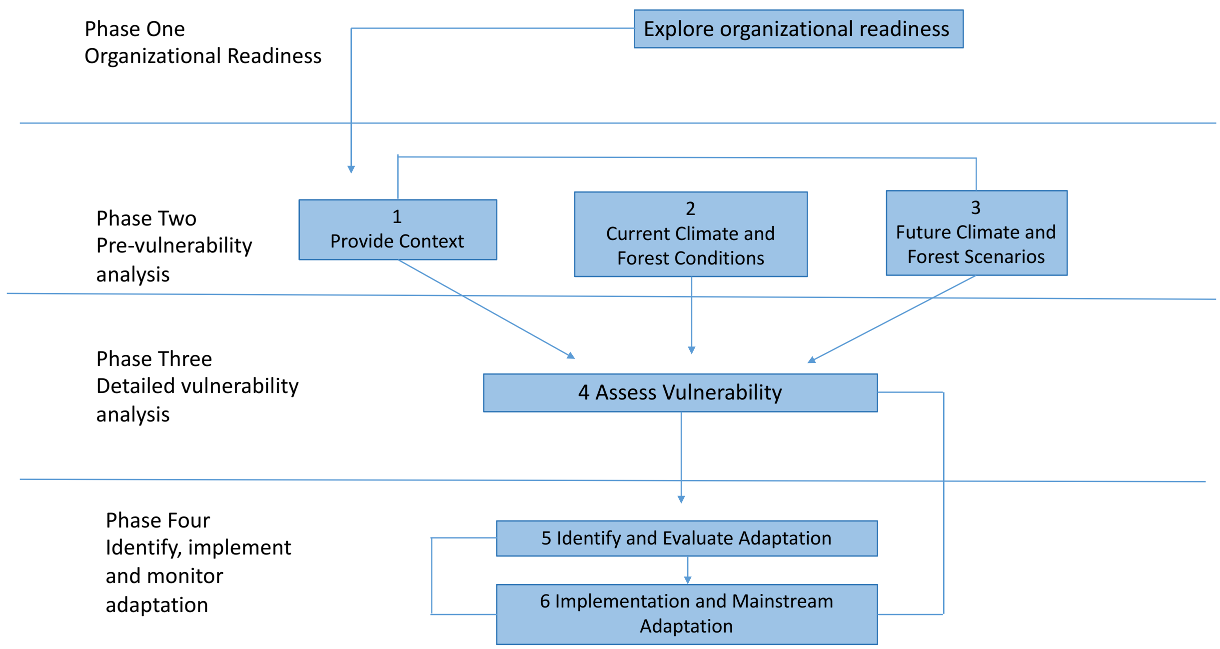

Figure 4.1 The four phases and six stages of adaptation to climate change in the context of sustainable forest management (Williamson et al., 2012; Edwards et al., 2015).

"The CCFM vulnerability approach is an established methodology for providing information in a form that supports policy and decision making in the context of adapting to climate change" (Williamson et al., 2012). This vulnerability assessment framework also acknowledges and addresses uncertainty with respect to climate variability and allows forest managers and policy makers to develop and mainstream adaptation for SFM systems, with this in mind. Broad goals of this framework allow forest managers and policy makers to:

- "Identify where SFM is vulnerable to climate change and therefore where adaptation is needed.
- Identify and prioritize adaptation measures.
- Mainstream adaptation into decision making and policy" (Williamson et al., 2012).

The CCFM framework can also be applied at different scales and allows for an overall, comprehensive assessment of a complex socio-ecological system, under different policy and management structures (Williamson et al., 2012).

Information for the results of this research was also collected through interviews and meetings between the researchers, forest managers from the private sector, government, and other stakeholders, culminating with a half day workshop between the provincial government and forest managers involved in the CCFM vulnerability assessment. The workshop covered the following topics:

- For Researchers – Overview/summary of Mistik Vulnerability Assessment Case Study and results/outcomes.
- For Mistik Forest Managers- Recommendations/challenges/barriers to adaptation, plans for moving forward from a forestry sector perspective.
- For Government – Current approach to addressing the following:
    - broader policy flexibility and implementation of adaptation and how they see their role,
    - political will, strategy for moving forward in the spirit of collaboration,
    - addressing climate change and adaptation in SFM and forest policy and regulation design.
- Mechanisms and strategies for moving forward for both government and forest managers and the next steps for collaboration and partnership going forward from here.

The forest company involved in this project was Mistik Management Ltd. located in Meadow Lake, Saskatchewan. The timing for Mistik to be a partner in this project, was opportune, due to their 20–year Forest Management Plan (FMP) renewal process with the provincial government.

At the onset of the project, both the provincial government and Mistik agreed on the importance of the scope and direction of the project and came together to collaborate. This has been a co-production of work between the Government of Saskatchewan, Forest Service Branch, Mistik Management Ltd. and the University of Saskatchewan. The process and outcomes of the vulnerability assessment, adaptation development and mainstreaming, through this project, are presented in Chapters 2 and 3.

4.4 Results

Through the CCFM vulnerability assessment, forest managers assessed their SFM system vulnerabilities, adaptive capacity, and priority areas. They then moved on to development of potential adaptation options, identified challenges to those adaption options, considered opportunities for mainstreaming, and continued monitoring and evaluating. Through the assessment process, forest managers recognized that by undertaking this process, they had already begun to reduce the risks of adverse effects of climate change by becoming more aware of the vulnerabilities within their SFM system (e.g. access issues) (Mistik, 2017). This process has increased the adaptive capacity of their SFM system (Mistik, 2018). They have also come to understand more fully that with respect to climatic uncertainty, management decisions and actions of today and the immediate future will have impacts far into the future (IUFRO, 2009; Mistik, 2018).

In the beginning, the task of conducting the vulnerability assessment was viewed as being "too big to tackle" (Mistik, 2015). Some of the main concerns that were identified by both government and forest managers, included (Mistik, 2015; MoE, 2015):

- Do they have the necessary information and knowledge to do a vulnerability assessment on climate change?

- Do they have the appropriate tools in their SFM system to be able to develop, mainstream, monitor and evaluate adaptation options?
- How do they assess and manage for increasing climatic uncertainty into the future?
- Are the challenges and barriers able to be overcome to move forward with adaptation mainstreaming and policy flexibility?

With these overarching concerns in mind, both the Forest Service Branch of the Saskatchewan Government and Mistik Management Ltd. came to the decision that in spite of these concerns, it was time to move forward in this collaboration, to address these complex “real world” situations and recognize uncertainty through the vulnerability process and adaptive management to climatic risk (IUFRO, 2009). The consensus from the beginning of this project, was to collaborate in an effort towards co-production between government and forest managers on guiding policy. They agreed that it was also important to bring together science, management, and policy in decision-making in government and industry, addressing climate change impacts and variability (Cash et al., 2006).

Through the vulnerability assessment, Mistik developed an inventory of potential adaptation options that will aid in providing direction and guidance to the province for future research initiatives and broader policy concerns and focus. The following is an excerpt from this inventory to demonstrate some of the adaptation options and how they are related to governance, policy and regulatory challenges (full Table is in Appendix B).

Table 4.1 Selected Inventory of Adaptation Options from the Mistik Management Ltd., Vulnerability Assessment.

CCFM SFM Criterion	Climate Change Impact/Vulnerability	Forest Management Planning Level	Adaptation Options	Ranking 1- Desirable/Doable 2- Possible but harder to accomplish 3- Remote but tough 4- Not feasible (NF)
Biological Diversity	**Alteration of plant and animal distribution**	Strategic	Protect most highly threatened species ex situ. (Focus at habitat-from species concept)	4 Policy and regulatory challenges.
Biological Diversity	**Alteration of plant and animal distribution**	Strategic	Create artificial reserves or arboreta to preserve rare species	4 Policy/Regulation/Financial challenges (wood supply concerns; proposed in Alberta with respect to Caribou – not well received)
Ecosystem condition and productivity	**Increased frequency and severity of insect and disease disturbance**	Operational	Shorten the rotation length to decrease the period when stands are vulnerable to damaging insects and diseases and to facilitate change to more suitable species	4 Impractical Policy/Regulations/Financial challenges
Ecosystem condition and productivity	**Increased frequency and severity of insect and disease disturbance**	Operational	Increase the genetic diversity of trees used in plantations	4 Financial challenges Don't have plantations on FMA
Ecosystem condition and productivity	**Increased mortality due to climate stresses**	Strategic	Avoid planting new forests in areas likely to be subject to natural disturbances (e.g. Floods)	4 Impractical
Ecosystem condition and productivity	**Increased mortality due to climate stresses**	Operational	Minimize amount of edge created by human disturbances	4 Impractical Against current FM paradigm
Ecosystem condition and productivity	**Decreased forest growth**	Strategic	Adapt sivilcultural rules and policies to ensure the growth rates of trees is maintained or enhanced	1 No existing barriers or challenges
Ecosystem condition and productivity	**Decreased forest growth**	Operational	Include climate variables in growth and yield models to generate more specific predictions on the future development of forests	3 Need more understanding/knowledge/research Too much uncertainty (e.g. could burn within the current planning year…?) (Already have mixed wood growth models in Alberta)
Ecosystem condition and productivity	**Decreased health and vitality of forest ecosystems due to cumulative impacts of multiple stressors**	Strategic	Reduce non-climatic stresses by managing tourism, recreation, and grazing impacts to enhance ability of ecosystems to respond to climate change	4 Policy/Regulations challenges Not within forest managers authority to regulate
Ecosystem condition and productivity	**Decreased health and vitality of forest ecosystems due to cumulative impacts of multiple stressors**	Strategic	Pursue better and more cost-efficient methods of multi-scale monitoring systems for early detection of change in forest status and health	4 Provincial/Federal initiative and responsibility Policy/Regulations challenges More research necessary

CCFM SFM Criterion	Climate Change Impact/Vulnerability	Forest Management Planning Level	Adaptation Options	Ranking 1- Desirable/Doable 2- Possible but harder to accomplish 3- Remote but tough 4- Not Feasible (NF)
Role in global ecological cycles	**Decrease in forest sinks and increased CO_2 emissions from forested ecosystems because of increased frequency and severity of forest disturbance**	Operational	Decrease impact of natural disturbances on carbon stocks by managing fire and forest pests	4 Beyond mandate of company and impractical with respect to our SFM operations Provincial/Federal role
Role in global ecological cycles	**Forest management policies and incentives do not encourage adaptation to climate change**	Strategic	Provide incentives and remove barriers to enhancing carbon sinks and reducing greenhouse gas emissions	4 Policy/Regulation/Financial challenges
Role in global ecological cycles	**Forest management policies and incentives do not encourage adaptation to climate change**	Operational	Provide incentives for forest management activities to be included in carbon trading systems (e.g. As outlined in Article 3.4 of the Kyoto Protocol)	4 Policy/Regulations challenges
Economic and social benefits	**Increased frequency and severity of forest disturbance**	Operational	Protect higher-value areas from fire through FireSmart techniques	4 Policy/Regulation challenges Provincial jurisdiction and legislation
Economic and social benefits	**Forest management plans and policies lack the flexibility that is required to respond to climate change**	Strategic	Provide long-term tenures to encourage incorporation of long-term considerations within short-term decisions	4 Government provides the tenue Policy/regulation issue/concern
Society's responsibility	**Decreased socio-economic resilience**	Strategic	Review forest policies, forest planning, forest management approaches and institutions to assess the ability to achieve social objectives under climate change (e.g. conservation objectives)	4 Policy/Regulation challenges Provincial lead required here (Note: Mistik has started to work on this through the vulnerability assessment case study)
Society's responsibility	**Decreased socio-economic resilience**	Strategic	Evaluate the adequacy of existing environmental and biological monitoring networks for tracking the impacts of climate change on forest ecosystems, identify inadequacies and gaps in these networks and identify options to address them	4 Federal/Provincial joint iniative recommended Long-term monitoring regionally/nationally needed (Mistik is doing on a small scale of their FMA and through research with the vulnerability assessment case study)

(Adapted from Edwards et al., 2015).

These adaptation options are ranked from ‘one’ through ‘four,’ with the ones and twos being low-risk and ready for implementation without any barriers to mainstreaming (Mistik, 2018). The threes and fours are potential options for adaptation that have significant challenges and barriers and are more for long range planning and mainstreaming, depending on climate impacts and change in vulnerabilities in the future (Mistik, 2017). The inventory of adaptation options has been modified for Saskatchewan from the CCFM vulnerability assessment framework. The inventory of adaptation options aids in providing direction for forest managers and policy makers, when looking at broader forest management planning and regulations. It also helps define challenges and barriers that need to be addressed at a larger scale, beyond the scope of forest managers.

Through the vulnerability assessment process, challenges and barriers were identified (examples listed in the Table 4.1). Overall, these challenges and barriers decrease the effectiveness and capacity of forest managers to facilitate and mainstream adaptation within forest management (Klenk et al., 2011). According to the theory of adaptive systems, by identifying the potential challenges and barriers, from a forest management perspective, collaboration between government and forest managers will be stimulated. This leads to collaboration in finding applied solutions to barriers/challenges and provides the opportunity to focus on possibilities for becoming more pro-active in management, planning and policy modifications and development (Klenk et al., 2011). In practice, the workshop identified no fewer than 15 of 17 adaptation options as falling in the least tractable category and the reason frequently given is that such an option requires changes in the design of the forest policy framework, which falls outside the responsibility of forest managers in industry.

The following is a summary of the main challenges and barriers raised throughout the vulnerability assessment by the forest managers at Mistik Management Ltd. involved in the case study:

- Need for increased flexibility within existing policy/regulations to mainstream potential adaptation options in an applied, timely and effective manner (e.g. haul limit dates).
- Need for increased responsiveness of the government to adaptations being implemented in the "real world" context when timing is a key factor in addressing climatic variability within operations and planning (e.g. temporary stockpile site permits).
- Strengthened communication, understanding, and collaboration between different departments within the government, forest managers and stakeholders, with respect to climate change impacts, policy/regulation direction, and collaborative efforts.
- Greater understanding, education, and knowledge transfer between forest managers, government, academia, the public, and other stakeholders regarding climate change impacts and forest management.

In light of the recognition of challenges and barriers, Mistik Management has increased its adaptive capacity, awareness and understanding of some of the key obstacles that they are facing within adapting to climate change impacts (Mistik, 2017). Furthermore, this has increased the awareness of forest managers and government at a broader provincial and national level in Canada. This happened through the process of the vulnerability assessment. In order to further increase adaptive capacity, however, there needs to be increased communication between forest managers and government and increased collaboration to address these issues (Mistik, 2018; MoE, 2018). It has to become a point of departure to break down barriers and find alternatives and solutions. Through the meetings and work between the government and forest managers throughout this project, the outcomes from the vulnerability assessment have raised some difficult challenges (Mistik, 2018; MoE, 2018). However, what this has accomplished is an understanding by all those involved that in order to progress and adapt to climatic uncertainty, increased collaboration and communication between all parties is essential. It is also important that collaboration and communication increase internally within government and departments (Mistik, 2017).

Ultimately, the results of the collaboration between the forest managers and government identified a critical governance issue. Results-based management was originally intended to provide an incentive-based framework for arms-length management of provincial forests by licensees who would have the appropriate incentives to achieve SFM goals, including a healthy forest industry and sustainable forest-dependent communities. In the context of adaptation to climate change, results-based management must also function as a critical feedback mechanism that stimulates learning and, if necessary, a change in the design of forest policy to reduce vulnerability and build resilience. Managers have identified a menu of options that they think are worth pursuing. What is lacking is a governance framework to facilitate collaborative policy making on the basis of this crucial feedback. The framework needs to facilitate the kind of partnership that strives for a truer results-based approach integrating science, management, and policy to manage the forests for the future. Mistik recommends increased flexibility and responsiveness within policy/regulations in order to allow for "best" SFM practices in the face of increased climatic uncertainty and an increase in co-production between government and forest managers with respect to building flexibility into policy to build resilience.

4.5 Discussion

Forests are being affected by, and will continue to suffer, the impacts of climate change both directly and indirectly (CCFM, 2008). Forest management and policy need to adapt to the uncertainty created by climate change, and it is becoming clearer that forests cannot necessarily be managed the way they used to be. There is broad agreement that SFM practices and policy need to be better integrated, in a collaborative approach that includes greater flexibility, responsiveness and increased communication and education within policy to allow for climate change adaptation in SFM practices. By collaboration between government and industry and having policy that includes more focus on these elements, SFM management will be strengthened and increase the adaptive capacity for forest managers to adapt to adverse impacts of climate change (IUFRO, 2009; Mistik, 2018). In turn, this will promote better integration between policy design and on-the-ground management that has to be reconciled with the government's legal responsibilities with respect to the stewardship of Crown lands and their political responsibilities to the various stakeholders whose goals and interests have been recognized in forest policy.

Climate change research into impacts on forests has been going on for over 20 years. Along with the impacts research, vulnerability assessments have evolved, with the development of conceptual frameworks that address complex socio-ecological systems, such as forests (Edwards et al., 2015). These assessments are providing a framework for forest managers to assesses their SFM systems (e.g. the Mistik case study, using the CCFM approach), with the use of science and applied forest management planning and strategies to analyse vulnerabilities and prioritise them. Then they move towards developing and identify adaptation options for best practices and how to move forward with mainstreaming and monitoring these going into the future. Once this point is reached however, it is clear that many of the potential long-term adaptation strategies may be impeded by barriers such as increased investment, lack of technology or knowledge, certification limits, and limited support from government with respect to responsiveness and flexibility within policy, and communication challenges between stakeholders and agencies.

Collaboration and increased partnership between forest managers and government is a crucial component of successful mainstreaming adaption to climate change. Forest managers can only take adaption implementation so far, without support from government for collaborative policy change. Ansell et al., (2017) identify three components of collaborative policy design:

- Joint exploration of policy problems that create novel problem definitions, which emphasizes the urgency of the problem while demonstrating how it can be solved, even if these solutions are disruptive of existing policy frameworks,
- Careful evaluation of alternatives through joint assessment of risks and benefits in which science becomes a means to understand risk rather than a weapon to promote an agenda,
- Nurturing a sense of joint commitment to, and responsibility for, successful implementation.

The recommendations of the research-policy flexibility and responsiveness; increased internal and external communication; and increased education, awareness and understanding of the science and management applications within policy and regulations all point in this direction (Mistik, 2018). Through this project, the collaboration between forest managers and government has been one of the key ingredients that have led to the strengthening of establishing the partnership and direction between the Forest Service Branch and forest managers in Saskatchewan. This is a new direction for all parties involved. The provincial government is in the early stages of integrating climate change impacts and incorporating adaption into existing and future policy/regulations (MoE, 2015). At this point, the government's direction is that they are moving forward to develop a framework for resilience for the entire province (so on a much broader, larger scale, not sector specific yet) and then once this has been finalized, there will then be direction for the specific branches and sectors on how to proceed from here. The government is in the process of developing a "province wide" climate change action plan. No specific climate change policy or regulations will be developed until 2019 at the earliest (A. Kuchirka, personal communication, March 27, 2018).

With the current government direction, the Forest Service Branch has begun, through this project, to establish a more collaborative partnership with forest managers that integrate the needs for adaptation into policy. The government is using the results of the Mistik case study to guide their broader policy direction. The Forest Service Branch is also looking at undertaking their own vulnerability assessment to determine their adaptive capacity and role in moving forward to integrate climate change adaptation into the broader forest management policy and regulations, under the overall climate change strategy for the province. They are in agreement with forest managers that integration of vulnerability and adaptation into policy design is required to increase the resilience and adaptability of forest management and forests. It is clear that forest policy must embrace the increasingly complex issues of climate change adaptation in SFM practices, and that policy development will have a major impact on the ability of forest managers to adapt management planning and practices dealing with increasing climatic uncertainty.

Through this project, a network of forest managers and government is being formed that is moving to coordinate the efforts for a greater integration of science, management, and policy to include:

- Long-term applied planning and research,
- Target and results-oriented governance,
- Climate change impacts integration,

- Cooperative governance,
- Participation and monitoring (Janicke and Jorgens, 2006; IUFRO, 2009).

Moving in this direction will help promote “the creation of interdependent bottom-up policy networks which ensure SFM” (IUFRO, 2009) and increased organizational resilience and adaptive capacity. The results of the project also demonstrate a move towards adaptive governance that focuses on the vulnerability of complex socio-ecological system of forests, forms of collaboration and partnerships, and knowledge building and transfer (IUFRO, 2009). This will help better prepare management for dealing with climatic uncertainty and support responsiveness and flexibility within policy.

However, from a government perspective, a question that must be considered as we move forward, is how much flexibility can be built into policy before the ability for appropriate regulating and enforcement capacity has been lost? Forest managers have many complex goals that they must consider within their SFM systems, but competitiveness is the predominant one. How can they continue to improve their competitiveness (which will be affected by climate change) and adapt “best” practices? Working towards a new governance framework can be complex when dealing with the different goals and mandates of those involved. A challenge will be going from the traditional regulator-forest manager roles, towards a more adaptive governance structure and results-based approach where there is a complex melding of different values.

Communication is another important factor where increased efforts could be focused to aid in the development and understanding of needs required for integration of climate change science and adaptation into policy (Mistik 2016, 2017, 2018). Communication between forest managers and government has its complexities, especially when addressing the standard “regulator” – “industry” structure of the past and current relationship. Through the collaborative efforts of this project, industry forest managers and Forest Service Branch, have taken the beginning steps toward approaching these issues in a more collaborative spirit. Communication will be a key factor in the progress and success of a more cooperative working relationship. Increasing communication internally, between different government departments will also be beneficial for guiding future policy development. Responsiveness and flexibility will help strengthen the policy changes to help address climate change impacts in a more meaningful way for management and across agencies within government (Mistik, 2017).

Along with developing and modifying policy and regulations to incorporate responsiveness, flexibility and expanding communication strategies, relationships and understanding between forest managers and government internally and externally, will be strengthened. Education and knowledge transfer are also important elements in this success. Disseminating and communicating the science, management applications, policy and regulation roles within these complex issues is recognized through this project, as being an integral part of providing more robust and resilient adaptation options and understanding how to maintain policy and regulations that legislate the laws, while still providing enough flexibility within them to allow managers to respond within an appropriate time frame to address climatic uncertainty (Mistik, 2018).

4.6 Conclusions and Recommendations

We completed an assessment of climate change impacts and vulnerability for a SFM system. It was enabled and supported by collaboration of government and forest managers, in Saskatchewan, Canada. Through this work, it has become more evident, that building and strengthening the partnership between government and forest managers to move in a direction for adaptive governance and a truer results-based approach to climate change adaptation within

SFM, is crucial. This will build resilience to climatic uncertainty. Climate change is already bringing situations where responsiveness and flexibility for “on the ground” applications by forest managers is required without having to go back to government and go through “a lengthy approval process” for every adaptation that is required (e.g. Miscellaneous Use Permit for temporary stockpile) (Mistik, 2018). Based on the Mistik case study and others that the Forest Service Branch has committed to participating in over the next two years, the results of this study will help guide and shape their goals and objectives (strategic direction) for broader policy implications and needs. This will allow for setting clearer priorities internally, as they work on including these issues in policy and regulation design for the future. This will help with the longer term strategic direction. It will also provide greater policy analytical capacity to aid in decision making, increasing responsiveness and flexibility, stronger communication internally and externally, increased knowledge transfer and dissemination, and for improved coordination of policy networks between federal, provincial and industry government levels (Wellstead and Stedman, 2007).

In Saskatchewan, as in many other jurisdictions, forest policy strives to reconcile these objectives by means of a results-based approach to regulation and forest management. The results-based approach is presented as a credible response to address the uncertainties of climate change and adaptation within a broader policy framework of sustainable forest management. Using the results of the case study, the province will be able to apply the results-based approach to integrate adaptation, flexibility, increased communication and responsiveness into policy. The results of this case study will also be utilized for helping guide and shape future research initiatives, and policy modification or development, where necessary.

The development of communication strategies between departments and forest managers and the collaboration and use of interagency networks will promote more effective adaptation to climate change impacts. Within government, there are separate mandates, agendas, policy and regulation that that may affect other sectors (e.g., Wildfire Management Branch policy affecting forest management practices) (Mistik, 2018). Forest-sector responses to climate impacts may cross departments. Policies and regulations that affect management decisions within the forest sector, sometimes are a result of other "non-forest" drivers. In order to build strength and adaptive capacity within forest management and policy dealing with climate change adaptation, it is imperative that communication, collaboration, and knowledge transfer flows within all levels of government (IUFRO, 2009).

The Forest Service Branch is using the results of this vulnerability assessment to analyze their own internal vulnerabilities and adaptive capacity as a regulator and policy maker. It will also help them develop priorities and a strategy for broader policy initiatives to promote responsiveness and flexibility for climate change adaptation. This is a significant step within climate change adaptation and policy. The Forest Service Branch, and the broader provincial government, is moving forward from this point to continue increasing communication and collaboration with forest managers and is participating in an integrated regional assessment, using the CCFM framework with two other forest industry partners in Saskatchewan, who will be doing a vulnerability assessment of their SFM systems. Forest managers and government from the Province of Manitoba are also collaborating on this project. The integrated assessment will be building a network of forest managers and provincial government agencies that will strengthen, build resilience and opportunities for reducing risks of climate change impacts and increase the ability for adaptation.

Adapting policy and governance structures can be a slow and difficult task and bringing forest managers and policy makers together to partner to adapt and design policy, has significant challenges. In many ways, climate change adaptation in the forest sector is in its infancy, but at least the first steps have been taken. The will is there by the key players to commit to this collaboration. Some of the recommended steps for increasing the capacity of those involved moving forward, include:

- Increased education and knowledge dissemination for industry forest managers and government department staff on climate change impacts, vulnerabilities, adaptation, and policy flexibility;
- Increased communication and collaboration between government staff, forest managers, other stakeholders, and the public;
- Building trust between government, forest managers and the public. This would help in changing the perception of the government being seen as just the “regulator” and would demonstrate collaboration and support;
- Exploring the idea of creating an interagency body to communicate and collaborate across sectors and agencies to establish a network for climate change policy development and guidance;
- Increased flexibility and responsiveness within policy/regulations in order to allow for “best” SFM practices in the face of increased climatic uncertainty and an increase in co-production between government and forest managers with respect to building flexibility into policy to build resilience.

Adaptation has been developed and is already being mainstreamed into Mistik’s SFM system. In the next steps, policy makers are seizing the opportunity to adapt and design policy that will include responsiveness and flexibility to respond to climate impacts in the future. The outcome of this work is providing guidance to both forest managers and policy makers within Saskatchewan and can also be applied at a national level and across other natural resource sectors.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS – VULNERABILITY AND ADAPTATION TO CLIMATE CHANGE IN SUSTAINABLE FOREST MANAGEMENT IN SASKATCHEWAN

5.1 Introduction

Decisions regarding the development and mainstreaming of adaptation within sustainable forest management and the forests have significant implications for the ability of these complex socio-ecological systems to remain sustainable in the future as climate change impacts become more deleterious over time (Halofsky et al., 2018). Strategic climate change vulnerability assessments, a tool used to, evaluate and assess climatic impacts on forests, add value to higher level strategic decision-making and policy development, as well as day-to-day operations within the forest sector. Climate change vulnerability assessments are a valuable tool to facilitate adaptation within climatic uncertainty as forest managers are expected to evaluate and assess climate change impacts in their SFM systems and make informed choices about the longer-term sustainability (Edwards et al., 2015).

The purpose of this thesis was to examine the relationship between SFM, climate change impacts and vulnerability, and adaptation mainstreaming in SFM systems. Development of adaptation options and tools for evaluating, monitoring, implementing and mainstreaming adaptation into existing SFM systems was one of the main applications that came out of this project. The intent was to advance the application of vulnerability assessments on SFM systems and demonstrate the integration and operationalising of adaptation to climate change impacts into all elements of an SFM system. The results of the vulnerability assessment have also provided guidance for governance and policy issues surrounding SFM and forests. This was accomplished by the following objectives:

i. Complete a vulnerability assessment using the CCFM Framework for Assessing Vulnerability and Mainstreaming Climate Change into SFM as a tool to assess and prioritize vulnerabilities within an SFM system and report on the process of forest managers applying the tool to an industry SFM system to support the vulnerability assessment process for use by other forest managers;
ii. Identify and develop science-management adaptation options, evaluation, monitoring, implementation and mainstreaming tools for forest managers;
iii. Demonstrate, based on a case study, the mainstreaming of low-risk, applied adaptation management practices in Saskatchewan;
iv. Provide suggestions and guidance to the Saskatchewan Provincial Government, Forest Service Branch for development and modification of climate related forest policy and potential barriers and challenges that exist within SFM systems and policy and regulations.

Industry and government were able to aid in the advancement and improvement of science-based management options and adaptation tools for mainstreaming adaptation into SFM. We also provided guidance and suggestions for increasing policy responsiveness, flexibility, development and modification.

5.2 Vulnerability Assessment

In the first part of this project, it was determined that the CCFM Guidebook for Assessing Vulnerability and Mainstreaming Adaptation into Decision-Making (Edwards et al., 2015) would be used for conducting a case study involving industry forest managers in collaboration with the provincial government. Through this project, the case study with Mistik was the first of its kind completed from start to finish in Canada, which is an important contribution to adaptation development and mainstreaming.

The process of undertaking a vulnerability assessment focusing on climate change at the FMA scale, seemed daunting to government and the forest managers involved. However, by following the structured decision-making approach of the CCFM framework, managers were able to assess their organizational readiness and realize that they had the tools and resources to initiate the assessment on their SFM system.

Through the process of implementing the vulnerability assessment, it became evident that the CCFM framework is a useful tool to help industry forest managers. It aids in the assessment of their SFM system (at all levels), for developing a context for the assessment that is specific to their SFM system and landbase. It also identifies and assesses current and future climate vulnerabilities, then provides steps for ranking these vulnerabilities according to their specific SFM priorities. As the managers completed the different stages of the vulnerability assessment, their conceptual approach to climate change transformed from being completely separate from all other parts of their SFM system, to one that was being considered as part of their SFM system as a whole. When mainstreaming adaptation started to become part of their SFM planning and operations, this, in turn, led to an increase in their adaptive capacity, leading to the understanding that adaptation was necessary as they move into greater uncertainty surrounding climatic impacts on forests and management.

5.3 Adaptation and Mainstreaming

Through the next two objectives of the project, the focus was on adaptation and mainstreaming. Taking the results from the detailed vulnerability analysis and the decision that adaptation is necessary for "best practices" within SFM, the next steps involved identifying, implementing, and monitoring for adaptation. At the beginning of this stage, the managers were again, feeling overwhelmed and not sure where to start to begin developing and assessing potential climate change adaptation for SFM objectives and indicators. The CCFM framework provides an inventory of potential adaptation options (Edwards et al., 2015). Using this inventory as a starting point, the forest managers assessed and modified the adaptation options presented with respect to applicability to their SFM system. They then ranked the options from one through four for ease of application and risk. The ones and twos were viewed as "low-risk", easily mainstreamed options that didn't present any challenges or barriers for mainstreaming. The threes and fours were assessed as having significant challenges and barriers attached to them, that would need to be addressed before they would be potential options for mainstreaming. The threes and fours were also seen as options that could become more feasible into the future, based on climate impacts and changes within SFM system vulnerabilities.

Mistik was able to use the adaptation inventory as a tool that has been mainstreamed into their SFM system that will be added to and modified as needed. Mistik also identified other tools in their SFM system that have enabled them to mainstream climate change adaptation as well. These include their internal Standard Operating Procedures, EMS system, and FMP process. Through identifying these in the case study, it has provided "real world" examples for other forest managers to assess and mainstream adaptation into their SFM systems to address and manage for climate change and increasing uncertainty.

5.4 Policy and Governance

At the onset of this project, the Saskatchewan Provincial Government has played an important role as a key collaborator. It was the Forest Service Branch who originally identified the need to address climate change impacts, vulnerability, and adaptation within SFM. They recognized the importance of collaborating with an industry partner in a vulnerability assessment and providing guidance on implementing and mainstreaming of adaptation within SFM. Based on the results of the Mistik case study, the provincial government now has identified broader forest policy and regulation implications for climate change. Increased collaboration and communication between forest managers and government has led to the following:

- increased understanding surrounding barriers and challenges that can impede adaptation implementation and mainstreaming,
- clearer understanding of need to determine where increased responsiveness and flexibility within policy and regulations may lead to more effective and efficient adaptation within forest management planning and practices,
- increased communication and development of policy networks between government departments, other agencies, and forest managers is also an area that requires more effort and development to aid in adaptation.

5.5 Challenges and Barriers

Challenges and barriers are present in any type of natural resource management. Identifying these issues from the forest manager's perspective has provided an opportunity for increased communication and collaboration for forest managers, government, First Nations, and other stakeholders. The following is a list of some of the potential challenges and barriers that were highlighted throughout the research project (Mistik, 2018):

- Financial barriers/challenges (e.g. potential new equipment needs for harvesting, increased infrastructure for road building for access),
- Policy/regulation barriers/challenges (e.g. limits for adaptation in policy/regulation flexibility and responsiveness),

- Addressing climate change issues under Acts from different jurisdictions (e.g. Wildfire Branch, SK),
- Education/awareness challenges (e.g. access and understanding for most up-to-date science-management application, public perceptions of climate change and the impacts on boreal forest ecosystems and management),
- Communication challenges/barriers (e.g. between different government agencies and departments, between industry forest managers and government),
- Knowledge/information challenges and barriers (e.g. having strong evidence based science for applied adaptation options, increased accuracy in climate models at the FMA level).

The process of identifying the challenges and barriers has increased the adaptive capacity of those involved by having increased knowledge of the limits that exist with potential adaptation options. Understanding these limitations better provides the opportunity to move towards increasing research, partnerships, education, and collaboration to find solutions that will enable sound, applied adaptation options for increased sustainability SFM.

5.6 Future Directions and Concluding Remarks

Uncertainty is a given within the field of climate change impacts and adaptation, especially as we move further into future time horizons. We know that complex socio-ecological systems of forests and forest management are being affected by highly variable climate change impacts. The science on climate change impacts is fairly comprehensive, however there is always more to learn and advance on. Furthermore, the science and application of adaptation in "real world" situations are still in their infancy (Halofsky et al., 2018). As more case studies and examples are coming to light, more evidence and tools for mainstreaming will become accessible. Potential adaption inventories are being developed and can be modified and mainstreamed for forest management systems in other parts of Canada and around the world. The tools that have been utilized and developed in the CCFM framework and through this case study example may also be adapted for use in other SFM systems for mainstreaming of climate change adaptation and could also be adapted across sectors.

Moving forward for the future, collaboration, research, completion of vulnerability assessments for climate change, communication and networking, and dissemination of knowledge must be promoted among forest managers, researchers, and government (Williamson et al., 2012). As more forest managers engage in the process of vulnerability assessment and adaptation mainstreaming, stronger evidence and application of science-management adaptation will also lead to increased understanding and informed policy development and flexibility guidance (Halofsky et al., 2018). This will also aid in minimizing and addressing climate change impacts more effectively.

In Canada, work is continuing to move ahead with research initiatives being supported by federal/provincial/industry/researcher collaborators. Four more vulnerability assessments are in the early stages of beginning with projects in Saskatchewan, Manitoba, and Ontario. These projects will be undertaking the same process as Mistik did, with the CCFM approach assessing SFM vulnerabilities at the FMA level, then moving to develop and mainstream adaptation. The results of the Mistik case study are already aiding in guiding these new initiatives in Canada.

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APPENDIX A: ASSESSMENT AND PRIORITIZATION OF MISTIK'S SFM OBJECTIVES AND ADAPTIVE CAPACITY UNDER CURRENT AND POTENTIAL FUTURE CLIMATE CHANGE

Assessment and prioritization of SFM objectives and Mistik's adaptive capacity under current and potential future climate change.

SFM Objectives	Current Forest Condition			Forest Impact Scenario 1 (2010-2039)		Forest Impact Scenario 2 (2040-2069)		Forest Impact Scenario (2070-2099)		Prioritization ranking of SFM objectives for management and planning purposes
	SFM Objective Impact	**Adaptive Capacity**	**Vulnerability**	**SFM Objective Impact**	**Vulnerability**	**SFM Objective Impact**	**Vulnerability**	**SFM Objective Impact**	**Vulnerability**	**Ranking**
CCFM Criterion 1: Biological Diversity										
Protected Areas and sites of Special Biological Significance – Respect protected areas identified through government processes. Cooperate in broader landscape management related to protected areas and sites of special biological and cultural significance. Identify sites of special geological, biological or cultural significance within the FMA and implement strategies appropriate to their long-term maintenance.	Low	High	Low	Medium	Low	Medium	Medium	High	High	1 (there are 5 SFM objectives ranked in Criterion 1)
Species Diversity – Conserve species diversity by ensuring that habitats for the native species found in the FMA are maintained through time, including habitats for known occurrences of species at risk.	Low	High	Low	Low	Low	Medium	Medium	High	Medium/High	2
Ecosystem Diversity – Conserve ecosystems diversity at the stand and landscape level by	Low	High	Low	Low	Low	Medium	Low/Medium	High	High	3

maintaining the variety of communities and ecosystems that naturally occur in the FMA.										
Genetic Diversity – Conserve genetic diversity by maintaining the variation of genes within species and ensuring that reforestation programs are free of genetically modified organisms.	Low	High	Low	Low	Low	Medium	Low	High	High	4
Forest Land Conversion – deletions to the forest area, permanent losses to the productive landbase	Low	High	Low	Low	Low	Medium	Medium	High	High	5
CCFM Criterion 2: Ecosystem Condition and Productivity										
Manage for regeneration success.	Low	High	Low	Low	Low	Medium	Medium	High	High	1 (there are 9 SFM Objectives ranked in Criterion 2)
Forest Growth, Mortality &/or Productivity – Productivity is directly related to Annual Allowable Cut (AAC) and is affected by changes in temperature and precipitation	Low	Medium/High	Low	Low	Low	Medium	Medium	High	High	2
Forest Ecosystem Productivity – Conserve forest ecosystem productivity and productive capacity by maintaining ecosystem conditions that are capable of supporting naturally occurring species. Reforest promptly and use tree species ecologically suited to the site.	Low	High	Low	Low	Low	Medium	Medium	High	Medium/High	3
Forest Ecosystem Resilience – Conserve ecosystem resilience by maintaining both ecosystem processes and ecosystem conditions.	Low	High	Low	Low	Low	Medium	Medium	High	Medium/High	4
Manage and minimize for increased frequency,	Medium	Medium	Medium	High	High	High	High	High	High	5

intensity, severity, or magnitude of forest fires.										
Manage for increase in severe weather events (increase frequency/intensity) – e.g. blowdown	Medium	Medium	Medium	High	Medium	High	High	High	High	6
Manage for increase in frequency and severity of insect/disease outbreaks – e.g. dwarf mistletoe always present, but may increase with changes in climate.	Medium	Medium	Medium	High	High	High	High	High	High	7
Manage for non-indigenous insect/disease	Low	Medium	Low	Medium	Medium	High	High	High	High	8
Manage for treeline change	Low	High	Low	Low	Low	Medium	Low	High	High	9
CCFM Criterion 3: Soil and Water										
Water Quality and Quantity – Conserve water resources by maintaining water quality and quantity.	Low	Medium	Low	Low	Low	Medium	Medium	Medium	Medium	1 (there are 8 SFM Objectives in Criterion 3)
Soil Quality and Quantity – Conserve soil resources by maintaining soil quality and quantity.	Low	Medium/High	Low	Low	Low	Medium	Low	Medium	Medium	2
Manage for changes in access due to length of winter road season changing.	Medium	Medium/High	Medium	Medium	Medium	High	High	High	High	3
Manage for changes in length of season when ground and water bodies are frozen.	Medium	Medium	Medium	Medium	Medium	High	High	High	High	4
Manage for increase in beaver activity.	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	5
Roads – increase in bridge and culvert infrastructure.	Low	High	Low	Low	Low	Medium	Low	Medium	Medium	6
Minimize increase in infrastructure for access – roads (bridge & culvert infrastructure), drainage structures.	Low	High	Low	Medium	Medium	Medium	Medium	High	High	7
Manage for timing and peak levels of stream flows.	Low	Medium	Low	Low	Low	Medium	Medium	Medium	Medium	8
CCFM Criterion 4: Role in global ecological cycles.										

Carbon Uptake and Storage – Maintain the processes that take carbon from the atmosphere and store it in forest ecosystems.	Low	Medium	Low	Low	Low	Low/Medium	Low	Medium/High	Medium/High	1 (there are 2 SFM Objectives in Criterion 4)
Forest Land Conversion – Manage for deletions to the forest area – Protect forestlands from deforestation or conversion to non-forests, where ecologically appropriate.	Low	High/Medium	Low	Low	Low	Low	Low	Medium	Medium	2
CCFM Criterion 5: Economic and Social Benefits										
Timber and Non-Timber Benefits – Manage the forest sustainably to produce an acceptable and feasible mix of timber and non-timber forest products and forest-based services.	Low	Medium/High	Low	Medium	Medium	Medium	Medium	Medium/High	Medium	1 (there are 9 SFM objectives in Criterion 5)
Manage for sustainable non-timber resources – All commodities uses and experiences.	Low	High	Low	Low	Low	Medium	Medium	High	High	2
Manage for change in timber supply.	Low	Medium/High	Low	Low	Low	Medium	Medium	High	High	3
Mange for increase in operating costs due to impacts of climate change within the FMA.	Medium	Medium	Medium	High	High	High	High	High	High	4
Manage for levels of investment – initiatives that contribute to community sustainability.	Low	Medium	Low	Medium	Medium	Medium	Medium	High	High	5
Communities and Sustainability – Contribute to the sustainability of communities by providing diverse benefits from forests and by supporting local community economies.	Low	Medium/Low	Low	Medium	Medium	Medium	Medium	High	High	6
Manage for changing economic opportunities.	Low	Medium/Low	Low	? – unsure	? - unsure	? - unsure	? – unsure	? - unsure	? - unsure	7

Manage for a decrease in non-timber forest products.	Low	Medium	Low	Medium	Medium	High	High	High	High	8
Manage for a change in timber supply.	Low	Low/Medium	Medium	Medium	Medium	High	High	High	High	9
CCFM Criterion 6: Society's Responsibility										
Fair and Effective Decision-Making – Demonstrate that the SFM public participation process is designed and functioning to the satisfaction of the participants and that there is general public awareness of the process and its progress.	Low	High	Low	Low	Low	Low	Low	Low	Low	1 (there are 4 SFM objectives in Criterion 6)
Aboriginal and Treaty Rights – Recognize and respect Aboriginal title and rights and treaty rights. Understand and comply with current legal requirements related to Aboriginal title and rights, and treaty rights.	Low	High	Low	Low	Low	Low	Low	Low	Low	2
Respect for Aboriginal Forest Values, Knowledge and Uses – Respect traditional Aboriginal forest values, knowledge and uses identified through the Aboriginal input process.	Low	High	Low	Low	Low	Low	Low	Low	Low	3
Forest Community Well-being and resilience – Encourage, co-operate with, or help to provide opportunities for economic diversity within the community.	Low	High	Low	Low	Low	Low	Low	Low	Low	4

(Adapted from Table 4.3 in Edwards et al., 2015).

APPENDIX B: INVENTORY OF ADAPTATION OPTIONS MODIFIED BY MISTIK MANAGEMENT LTD.

CCFM SFM Criterion	***Climate Change Impact/Vulnerability***	***Forest Management Planning Level***	***Adaptation Options***	***Feasibility Ranking 1 – Desirable/Doable 2-Possible but harder to accomplish 3-Greater difficulty for feasibility and implementation 4- Not Feasible***	***Potential Challenges/Barriers/ Recommendations***
Biological diversity	**Alteration of plant and animal distribution**	Strategic	Minimize fragmentation of habitat and maintain connectivity	1	
Biological diversity	**Alteration of plant and animal distribution**	Strategic	Maintain representative forest types across environmental gradients in reserves	1	
Biological diversity	**Alteration of plant and animal distribution**	Strategic	Protect primary forests (e.g. Forests largely undisturbed by human activities)	1	
Biological diversity	**Alteration of plant and animal distribution**	Strategic	Protect climate refugia at multiple scales	1	
Biological diversity	**Alteration of plant and animal distribution**	Strategic	Identify and protect functional groups and keystone species	2 – 3	Policy/Regulation challenges
Biological diversity	**Alteration of plant and animal distribution**	Strategic	Provide buffer zones for adjustment of reserve boundaries	1	
Biological diversity	**Alteration of plant and animal distribution**	Strategic	Protect most highly threatened species ex situ (Focus @ habitat – from species concept)	4	Policy/Regulations challenges
Biological diversity	**Alteration of plant and animal distribution**	Strategic	Develop a gene management program to maintain diverse gene pools	4	Financial barriers – Millions of $$$ needed; needs to be national/provincial initiative; very specific research. Regulation barriers: Mistik must use local seed source according to provincial SFM policy/regulations.
Biological diversity	**Alteration of plant and animal distribution**	Strategic	Strategically increase size and number of protected areas, especially in 'high-value' areas	1	
Biological diversity	**Alteration of plant and animal distribution**	Strategic	Ensure that conservation corridors extend across environmental gradients	1	

CCFM SFM Criterion	***Climate Change Impact/Vulnerability***	***Forest Management Planning Level***	***Adaptation Options***	***Feasibility Ranking 1 – Desirable/Doable 2-Possible but harder to accomplish 3-Greater difficulty for feasibility and implementation 4- Not Feasible***	***Potential Challenges/Barriers/ Recommendations***
Biological diversity	**Alteration of plant and animal distribution**	Strategic	Ensure that infrastructure investments do not interrupt conservation or riparian corridors	1	
Biological diversity	**Alteration of plant and animal distribution**	Strategic	Increased regional cooperation in management of both protected areas species	1	
Biological diversity	**Alteration of plant and animal distribution**	Strategic	Create artificial reserves or arboreta to preserve rare species	4	Policy/Regulations/Financial challenges (wood supply concerns; proposed in Alberta with respect to Caribou-not well received)
Biological diversity	**Alteration of plant and animal distribution**	Operational	Emulation of NRV forestry	1	
Biological diversity	**Alteration of plant and animal distribution**	Operational	Assist changes in the distribution of species by introducing them to new areas	4	Policy/Regulations challenges
Biological diversity	**Alteration of plant and animal distribution**	Operational	Establish 'neo-native forests	4	Policy/Regulations challenges
Biological diversity	**Alteration of plant and animal distribution**	Operational	Increase the colonizing capacity in areas between existing habitat and potential new habitat	4	Policy/Regulations/Financial challenges Very broad based
Biological diversity	**Alteration of plant and animal distribution**	Operational	Design tree plantations to have a diverse understory (Mistik already has diverse regenerating areas)	1	
Biological diversity	**Alteration of plant and animal distribution**	Operational	For planted forests, establish indigenous, mixed-species stands, maximize natural genetic diversity, mimic the structural properties of the surrounding forests and avoid direct replacement of native ecosystems	1	
Biological diversity	**Increased frequency and severity of forest disturbance**	Strategic	Maintain natural fire regimes	4	Beyond reasonable control, especially by Mistik

CCFM SFM Criterion	***Climate Change Impact/Vulnerability***	***Forest Management Planning Level***	***Adaptation Options***	***Feasibility Ranking*** ***1 – Desirable/Doable*** ***2-Possible but harder to accomplish*** ***3-Greater difficulty for feasibility and implementation*** ***4- Not Feasible***	***Potential Challenges/Barriers/ Recommendations***
Biological diversity	**Increased frequency and severity of forest disturbance**	Strategic	Reduce the rate of deforestation and forest degradation	1	
Biological diversity	**Increased frequency and severity of forest disturbance**	Strategic	Maintain under and above-ground seed sources (seed banks or trees)	1	
Biological diversity	**Increased frequency and severity of forest disturbance**	Operational	Allow forests to regenerate naturally following disturbance wherever appropriate	1	
Biological diversity	**Increased frequency and severity of forest disturbance**	Operational	Prefer natural regeneration wherever appropriate	1	
Biological diversity	**Increased frequency and severity of forest disturbance**	Operational	Reduce fire hazard by implementing reduced impact logging, especially through reduction in the size of felling gaps and fuel loads	4	Policy/Regulations challenges Against current practices & impractical
Biological diversity	**Invasion of habitat by non-native species**	Strategic	Adopt policy to maintain integrity of ecosystems by avoiding disruption by non-native species	3	Policy/Regulations challenges
Biological diversity	**Invasion of habitat by non-native species**	Operational	Control invasive species	4	Policy/Regulations challenges Province to take the lead here. Very broad based
Ecosystem condition and productivity	**Increased frequency and severity of forest disturbance**	Strategic	Allocate forest landbase using a TRIAD approach to landscape zonation to identify areas that may be managed for timber production and where high intensity plantation forestry may be practiced	3	Counter to certification Against current practices

CCFM SFM Criterion	***Climate Change Impact/Vulnerability***	***Forest Management Planning Level***	***Adaptation Options***	***Feasibility Ranking 1 – Desirable/Doable 2-Possible but harder to accomplish 3-Greater difficulty for feasibility and implementation 4- Not Feasible***	***Potential Challenges/Barriers/ Recommendations***
Ecosystem condition and productivity	**Increased frequency and severity of forest disturbance**	Operational	Assist in tree regeneration	1	
Ecosystem condition and productivity	**Increased frequency and severity of forest disturbance**	Operational	Apply silvicultural techniques that maintain or increase species and structural diversity	1	
Ecosystem condition and productivity	**Increased frequency and severity of forest disturbance**	Operational	In drought-prone areas, increase the use of pre-commercial and commercial thinning to enhance the tolerance of the remaining trees and introduce drought-resistant species where appropriate	3	Impractical in current practices for Mistik
Ecosystem condition and productivity	**Increased frequency and severity of forest disturbance**	Operational	Actively manage forest pests	2-3	Financial/Policy/ Regulations challenges
Ecosystem condition and productivity	**Increased frequency and severity of insect and disease disturbance**	Strategic	Adjust harvest schedules to harvest stands most vulnerable to insect outbreaks	2-3	Too much uncertainty
Ecosystem condition and productivity	**Increased frequency and severity of insect and disease disturbance**	Strategic	Establish landscape level targets of structural or age class, for landscape connectivity for species movement, and of passive or active measures to minimize the potential impacts of fire, insects and diseases	1-2	
Ecosystem condition and productivity	**Increased frequency and severity of insect and disease disturbance**	Operational	Plant genotypes that are tolerant of drought, insects and/or disease	4	Policy/Regulation/ Financial challenges
Ecosystem condition and productivity	**Increased frequency and severity of insect and disease disturbance**	Operational	Reduce disease losses through sanitation cuts that remove infected trees	3	Financial challenges Could reduce wood volume/ha

CCFM SFM Criterion	***Climate Change Impact/Vulnerability***	***Forest Management Planning Level***	***Adaptation Options***	***Feasibility Ranking 1 – Desirable/Doable 2-Possible but harder to accomplish 3-Greater difficulty for feasibility and implementation 4- Not Feasible***	***Potential Challenges/Barriers/ Recommendations***
Ecosystem condition and productivity	**Increased frequency and severity of insect and disease disturbance**	Operational	Breed for pest resistance and for a wider tolerance to a range of climate stresses and extremes in specific genotypes	4	Policy/Regulations/Financial challenges Beyond Mistik's ability Needs to be a Federal/Provincial initiative
Ecosystem condition and productivity	**Increased frequency and severity of insect and disease disturbance**	Operational	Use prescribed burning to reduce fire risk and reduce forest vulnerability to insect outbreaks	4	Policy/Regulations challenges Liability/risk is too great
Ecosystem condition and productivity	**Increased frequency and severity of insect and disease disturbance**	Operational	Employ silvicultural techniques to promote forest productivity and increase stand vigour (i.e. Partial cutting or thinning) and thus reduce susceptibility to insect attack	2-3	Impractical on Mistik's FMA
Ecosystem condition and productivity	**Increased frequency and severity of insect and disease disturbance**	Operational	Shorten the rotation length to decrease the period when stands are vulnerable to damaging insects and diseases and to facilitate change to more suitable species	4	Policy/Regulations/ Financial challenges
Ecosystem condition and productivity	**Increased frequency and severity of insect and disease disturbance**	Operational	Increase the genetic diversity of trees used in plantations	4	Financial challenges Don't have plantations on FMA
Ecosystem condition and productivity	**Increased mortality due to climate stresses**	Strategic	Avoid planting new forests in areas likely to be subject to natural disturbances (e.g. Floods)	4	Impractical for Mistik's FMA
Ecosystem condition and productivity	**Increased mortality due to climate stresses**	Operational	Minimize amount of edge created by human disturbances	4	Impractical Against current FM paradigm
Ecosystem condition and productivity	**Decreased forest growth**	Strategic	Adapt silvicultural rules and policies to ensure the growth rates of trees is maintained or enhanced	1	

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Ecosystem condition and productivity	**Decreased forest growth**	Operational	Practice high intensity forestry in areas managed for timber production (to promote growth of commercial tree species) and where the forested landbase is allocated using a TRIAD approach to landscape zonation	3	Financial/Policy/ Regulations Impractical and against current SFM paradigm
Ecosystem condition and productivity	**Decreased forest growth**	Operational	Include climate variables in growth and yield models to generate more specific predictions on the future development of forests	3	Need more understanding/knowledge/ Research Too much uncertainty (eg. could burn within the current planning year…?) (Already have mixed wood growth models in Alberta)
Ecosystem condition and productivity	**Decreased forest growth**	Operational	Enhance forest growth through fertilization	3	Impractical (eg. Research has not supported this currently-past research done for Mistik by University of Saskatchewan work on ws & hybrid poplar)
Ecosystem condition and productivity	**Decreased forest growth**	Operational	Employ vegetation control techniques to offset drought	3	Impractical Financial challenges
Ecosystem condition and productivity	**Decreased forest growth**	Operational	Preform pre-commercial thinning or selectively remove suppressed, damaged or poor quality trees to increase resource availability to the remaining trees	3	Impractical Financial challenges
Ecosystem condition and productivity	**Decreased forest growth**	Operational	Plant genetically modified species	4	Certification issues – Absolutely NO!!! GMOs – NO!!! Policy/Regulations challenges No product stream
Ecosystem condition and productivity	**Decreased forest growth**	Operational	Identify more suitable genotypes	3	Impractical financially Too much risk

CCFM SFM Criterion	***Climate Change Impact/Vulnerability***	***Forest Management Planning Level***	***Adaptation Options***	***Feasibility Ranking 1 – Desirable/Doable 2-Possible but harder to accomplish 3-Greater difficulty for feasibility and implementation 4- Not Feasible***	***Potential Challenges/Barriers/ Recommendations***
Ecosystem condition and productivity	**Decreased forest growth**	Operational	Match provenances of trees to new site conditions	3	Impractical How do we know? Too much uncertainty.
Ecosystem condition and productivity	**Decreased forest growth**	Operational	Adjust the annual cut to maintain the forest processes in a state as close equilibrium as possible	2-3	Policy/Regulations challenges Do this on a 10-yr. cycle
Ecosystem condition and productivity	**Species are no longer suited to site conditions**	Strategic	Adapt silvicultural rules and practices to maintain optimum species-site relationships	2-3	Policy/Regulations challenges Needs to be made more specific to be a potential (eg. bigger Jp on outwashed sands?)
Ecosystem condition and productivity	**Species are no longer suited to site conditions**	Operational	Where current advanced regeneration is unacceptable as a source for the future forest, underplant with other species or genotypes	3	Financial challenges
Ecosystem condition and productivity	**Species are no longer suited to site conditions**	Operational	Design and establish a long-term multi-species / seedlot trial to test improved genotypes across a diverse array of climatic and latitudinal environments	4	Financial challenges Federal/provincial initiative
Ecosystem condition and productivity	**Species are no longer suited to site conditions**	Operational	Reduce the rotation age follow with planting to speed the establishment of better adapted forest types	3	Financial challenges Impractical in management
Ecosystem condition and productivity	**Species are no longer suited to site conditions**	Operational	Relax rules governing the movement of seed stocks from one area to another; examine options for modifying seed transfer limits and systems	2-3	Policy/Regulations challenges
Ecosystem condition and productivity	**Species are no longer suited to site conditions**	Operational	Use germplasm mixtures with high levels of genetic variation when planting	4	Policy/Regulations/Financial challenges

CCFM SFM Criterion	***Climate Change Impact/Vulnerability***	***Forest Management Planning Level***	***Adaptation Options***	***Feasibility Ranking 1 – Desirable/Doable 2-Possible but harder to accomplish 3-Greater difficulty for feasibility and implementation 4- Not Feasible***	***Potential Challenges/Barriers/ Recommendations***
Ecosystem condition and productivity	**Species are no longer suited to site conditions**	Operational	In plantations, avoid the use of clonal material selected purely on the basis of past growth rates	4	Financial challenges Use natural seed – do not have the ability
Ecosystem condition and productivity	**Invasions by non-native species**	Strategic	Adopt policies to ensure the disruption of ecosystems by non-native species is avoided	4	Policy/Regulations challenges
Ecosystem condition and productivity	**Invasions by non-native species**	Operational	Control undesirable plant species that will become more competitive in a changed climate	4	Policy/Regulation/Financial challenges Impractical
Ecosystem condition and productivity	**Increased nitrogen losses**	Operational	Use nitrogen fertilization or encourage nitrogen fixing species in the understory	3	Financial challenges Impractical
Ecosystem condition and productivity	**Decreased health and vitality of forest ecosystems due to cumulative impacts of multiple stressors**	Strategic	Reduce non-climatic stresses by managing tourism, recreation, and grazing impacts to enhance ability of ecosystems to respond to climate change	4	Policy/Regulations challenges
Ecosystem condition and productivity	**Decreased health and vitality of forest ecosystems due to cumulative impacts of multiple stressors**	Strategic	Reduce non-climatic stresses by regulating atmospheric pollutants to enhance ability of ecosystems to respond to climate change	4	Policy/Regulations challenges
Ecosystem condition and productivity	**Decreased health and vitality of forest ecosystems due to cumulative impacts of multiple stressors**	Strategic	Reduce non-climatic stresses by restoring degraded areas to maintain genetic diversity and promote ecosystem health to enhance ability of ecosystems to respond to climate change	4	This is a “Motherhood” statement!! Not feasible!!

CCFM SFM Criterion	***Climate Change Impact/Vulnerability***	***Forest Management Planning Level***	***Adaptation Options***	***Feasibility Ranking 1 – Desirable/Doable 2-Possible but harder to accomplish 3-Greater difficulty for feasibility and implementation 4- Not Feasible***	***Potential Challenges/Barriers/ Recommendations***
Ecosystem condition and productivity	**Decreased health and vitality of forest ecosystems due to cumulative impacts of multiple stressors**	Strategic	Monitoring all forests (not just production forests) at subnational and national scales through improved national, regional or operational forest health monitoring networks, harmonization of inventory and reporting protocols for such networks and through expansion and linkage of invasive species networks	4	Federal initiative
Ecosystem condition and productivity	**Decreased health and vitality of forest ecosystems due to cumulative impacts of multiple stressors**	Strategic	Pursue better and more cost-efficient methods of multi-scale monitoring systems for early detection of change in forest status and health	4	Provincial/Federal initiative/responsibility Policy/Regulations challenges
Ecosystem condition and productivity	**Decreased health and vitality of forest ecosystems due to cumulative impacts of multiple stressors**	Operational	Develop, test and improve risk assessment methods	1	
Ecosystem condition and productivity	**Decreased health and vitality of forest ecosystems due to cumulative impacts of multiple stressors**	Operational	In natural forests, ensure large juvenile population sizes to promote high genetic variation	2	
Ecosystem condition and productivity	**Decreased health and vitality of forest ecosystems due to cumulative impacts of multiple stressors**	Operational	Work with others to ensure that stressors outside the control of the forest manager (e.g. Atmospheric pollution) are minimized	4	No ability to influence Big issue for Mistik FMA due to Alberta oil patch and acid rain.
Ecosystem condition and productivity	**Decreased health and vitality of forest ecosystems due to cumulative impacts of multiple stressors**	Operational	Adopt a holistic management approach that balances timber and non-timber goods and services	1	

CCFM SFM Criterion	***Climate Change Impact/Vulnerability***	***Forest Management Planning Level***	***Adaptation Options***	***Feasibility Ranking 1 – Desirable/Doable 2-Possible but harder to accomplish 3-Greater difficulty for feasibility and implementation 4- Not Feasible***	***Potential Challenges/Barriers/ Recommendations***
Ecosystem condition and productivity	**Decreased health and vitality of forest ecosystems due to cumulative impacts of multiple stressors**	Operational	Maximize forest area by quickly regenerating any degraded areas	2	
Ecosystem condition and productivity	**Forest management plans and policies lack the flexibility that is required to respond to climate change**	Strategic	Relax rules governing the movement of seed stocks from one area to another	3	Provincial/Federal initiative Policy/Regulations challenges "Big maybe" here – more research in this area – how will we know what will be successful in an uncertain climatic future 85 years from now?
Soil and Water	**Increased soil erosion due to increased precipitation and melting of permafrost**	Strategic	Adopt policies to minimize the risk of sediment generation associated with roads and harvesting activities	1	
Soil and Water	**Increased soil erosion due to increased precipitation and melting of permafrost**	Operational	Maintain, decommission and rehabilitate roads to minimize sediment runoff due to increased precipitation and/or melting of permafrost	1	
Soil and Water	**Increased soil erosion due to increased precipitation and melting of permafrost**	Operational	Minimize soil disturbance through low impact harvesting activities	1	
Soil and Water	**Increased soil erosion due to increased precipitation and melting of permafrost**	Operational	Minimize density of permanent road network and decommission and rehabilitate roads to maximize productive forest area	1	
Soil and Water	**Increased soil erosion due to increased precipitation and melting of permafrost**	Operational	Limit harvesting operations to the winter to minimize road construction and soil disturbance	2-3	60% of work is in the winter…mills would need to carry extra wood supply – issues with capitol $$ being tied up. Practically desirable from an operations perspective.
Soil and Water	**Increased soil erosion due to increased precipitation and melting of permafrost**	Operational	Change road specifications to anticipate higher frequency of intense rainfall events	2-3	Policy/Regulations challenges Great deal of uncertainty, need to work more closely

CCFM SFM Criterion	***Climate Change Impact/Vulnerability***	***Forest Management Planning Level***	***Adaptation Options***	***Feasibility Ranking 1 – Desirable/Doable 2-Possible but harder to accomplish 3-Greater difficulty for feasibility and implementation 4- Not Feasible***	***Potential Challenges/Barriers/ Recommendations***
					with gov't. to establish flexibility, etc.
Soil and Water	**More/earlier snow melt resulting in changes in the timing of peak flow and volume in streams**	Strategic	Re-assess river and stream peak flows and link this information to design standards for bridges and roads	1	
Soil and Water	**More/earlier snow melt resulting in changes in the timing of peak flow and volume in streams**	Operational	Examine the suitability of current road construction standards and stream crossings to ensure they adequately mitigate potential impacts on infrastructure, fish, and potable water of changes in timing and volume of peak flows	1	
Role in global ecological cycles	**Decrease in forest sinks and increased CO2 emissions from forested ecosystems due to declining forest growth and productivity**	Strategic	Adopt policy to mitigate climate change through forest carbon management e.g. to minimize risk of the forest ecosystem becoming a net source of carbon	1	
Role in global ecological cycles	**Decrease in forest sinks and increased CO2 emissions from forested ecosystems due to declining forest growth and productivity**	Operational	Enhance forest growth and carbon sequestration through fertilization	3	Financial challenges – not good investment Impractical (eg. Based on past experiences)
Role in global ecological cycles	**Decrease in forest sinks and increased CO2 emissions from forested ecosystems due to declining forest growth and productivity**	Operational	Modify thinning practices (timing, intensity) and rotation length to increase growth and turnover of carbon	3	Financial challenges Impractical and against current SFM paradigm
Role in global ecological cycles	**Decrease in forest sinks and increased CO2 emissions from forested ecosystems due to declining forest growth and productivity**	Operational	Minimize density of permanent road network to maximize forest sinks	1	

CCFM SFM Criterion	***Climate Change Impact/Vulnerability***	***Forest Management Planning Level***	***Adaptation Options***	***Feasibility Ranking*** ***1 – Desirable/Doable*** ***2-Possible but harder to accomplish*** ***3-Greater difficulty for feasibility and implementation*** ***4- Not Feasible***	***Potential Challenges/Barriers/ Recommendations***
Role in global ecological cycles	**Decrease in forest sinks and increased CO2 emissions from forested ecosystems due to declining forest growth and productivity**	Operational	Decommission and rehabilitate roads to maximize forest sinks	1	
Role in global ecological cycles	**Decrease in forest sinks and increased CO2 emissions from forested ecosystems because of increased frequency and severity of forest disturbance**	Strategic	Identify forested areas that can be managed to enhance carbon uptake	2	
Role in global ecological cycles	**Decrease in forest sinks and increased CO2 emissions from forested ecosystems because of increased frequency and severity of forest disturbance**	Strategic	Identify areas that may be suitable for afforestation	4	Beyond company mandate – do not practice afforestation.
Role in global ecological cycles	**Decrease in forest sinks and increased CO2 emissions from forested ecosystems because of increased frequency and severity of forest disturbance**	Strategic	Identify areas where deforestation may be avoided	4	Policy/Regulations challenges Against regulations and do not do.
Role in global ecological cycles	**Decrease in forest sinks and increased CO2 emissions from forested ecosystems because of increased frequency and severity of forest disturbance**	Strategic	Identify areas where forests have been degraded and can be rehabilitated	2	
Role in global ecological cycles	**Decrease in forest sinks and increased CO2 emissions from forested ecosystems because of increased frequency and severity of forest disturbance**	Operational	Reduce forest degradation and avoid deforestation	1	

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Role in global ecological cycles	**Decrease in forest sinks and increased CO2 emissions from forested ecosystems because of increased frequency and severity of forest disturbance**	Operational	Decrease impact of natural disturbances on carbon stocks by managing fire and forest pests	4	Impractical Beyond company influence
Role in global ecological cycles	**Decrease in forest sinks and increased CO2 emissions from forested ecosystems because of increased frequency and severity of forest disturbance**	Operational	Minimize soil disturbance through low impact harvesting activities	1	
Role in global ecological cycles	**Decrease in forest sinks and increased CO2 emissions from forested ecosystems because of increased frequency and severity of forest disturbance**	Operational	Enhance forest recovery after disturbance	4	Financial challenges (ex. Blowdown, fire)
Role in global ecological cycles	**Decrease in forest sinks and increased CO2 emissions from forested ecosystems because of increased frequency and severity of forest disturbance**	Operational	Offset the use of fossil fuels by increase the use of forests for biomass energy	3	Desirable – however, challenges include financial – SaskPower is not supportive financially here. Economics play a significant role.
Role in global ecological cycles	**Decrease in forest sinks and increased CO2 emissions from forested ecosystems because of increased frequency and severity of forest disturbance**	Operational	Practice low intensity forestry and prevent conversion to plantations	1	
Role in global ecological cycles	**Forest management policies and incentives do not encourage adaptation to climate change**	Strategic	Provide incentives and remove barriers to enhancing carbon sinks and reducing greenhouse gas emissions	4	Policy/Regulations/Financial challenges

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Role in global ecological cycles	**Forest management policies and incentives do not encourage adaptation to climate change**	Operational	Provide incentives for forest management activities to be included in carbon trading systems (e.g. As outlined in Article 3.4 of the Kyoto Protocol)	4	Policy/Regulations challenges
Economic and social benefits	**Increased frequency and severity of forest disturbance**	Strategic	Include risk management in management rules and forest plans and develop an enhanced capacity for risk management	1	
Economic and social benefits	**Increased frequency and severity of forest disturbance**	Operational	Increase awareness about the potential impact of climate change on the fire regime and encourage proactive actions in regard to fuels management and community protection	2-3	Provincial role (regulator) – SK FireSafe program Mistik has done this on a small scale with individual communities (ex. Beauval – harvesting close to community).
Economic and social benefits	**Increased frequency and severity of forest disturbance**		Encourage appropriate capital investments, re-training of workforce and mobility of the population	4	Very broad People, generally want to be closer to home. Provincial initiative
Economic and social benefits	**Increased frequency and severity of forest disturbance**		Protect higher-value areas from fire through FireSmart techniques	4	Policy/Regulations Provincial role
Economic and social benefits	**Increased frequency and severity of forest disturbance**		Increase amount of timber from salvage logging of fire or insect disturbed stands	3	Financial challenges Alternative product-usually sub-grade (eg. Wind/fire
Economic and social benefits	**Decreased socio-economic resilience**	Strategic	Diversity forest economy (e.g. develop markets for dead wood products, value added products, non-timber forest products)	3	Not our mandate Provincial role
Economic and social benefits	**Decreased socio-economic resilience**	Strategic	Diversify regional economy (lesson dependence on the forest)	4	Provincial role Policy/regulations challenges

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					Some of these industries are very cyclic as well (eg. Wildrice).
Economic and social benefits	**Decreased socio-economic resilience**	Strategic	Expand tourism and recreational services to 3 or 4 season operations	4	Provincial role Nothing to do with company
Economic and social benefits	**Decreased socio-economic resilience**	Operational	Develop technology to use wood of altered quality and to use different tree species, modify wood processing technology	2	
Economic and social benefits	**Forest management plans and policies lack the flexibility that is required to respond to climate change**	Strategic	Provide long-term tenures to encourage incorporation of long-term considerations within short-term decisions	4	Government provides the tenure Policy/Regulations issue
Society's responsibility	**Erosion of local forest-related knowledge in forest-dependent societies**	Strategic	Support indigenous and local community efforts to document and preserve local forest-related knowledge and practices for coping with climatic variability and associated changes in forest structure and function	3	Social issue Do this directly/indirectly with PAG.
Society’s responsibility	**Erosion of local forest-related knowledge in forest-dependent societies**	Strategic	Incorporate study of local forest-related knowledge into forestry and environmental education	2-3	Provincial role – education curriculum Provincial policy and education outreach programs
Society's responsibility	**Erosion of local forest-related knowledge in forest-dependent societies**	Strategic	Promote research to examine the underlying ecological bases of traditional forest management practices	1	
Society's responsibility	**Erosion of local forest-related knowledge in forest-dependent societies**	Strategic	Encourage multidisciplinary, participatory research and dialogue between forest scientists and holders or users of local forest knowledge aimed at	2	

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			increasing adaptive capacity of both local ("informal") and formal science-based approaches to sustainable forest management		
Society's responsibility	**Decreased socio-economic resilience**	Strategic	Anticipate variability and change and conduct vulnerability assessments at a regional scale	1	
Society's responsibility	**Decreased socio-economic resilience**	Strategic	Enhance capacity to undertake integrated assessments of system vulnerabilities at various scales	2-3	Financial barriers - $$$ more research Doing through the Vulnerability Assessment Case Study
Society's responsibility	**Decreased socio-economic resilience**	Strategic	Establish objectives for future forest under climate change	2-3	Doing through the FMP Policy initiative – provide industry with scenario to anticipate
Society's responsibility	**Decreased socio-economic resilience**	Strategic	Review forest policies, forest planning, forest management approaches and institutions to assess the ability to achieve social objectives under climate change (e.g. conservation objectives)	4	Provincial lead here Policy/Regulations challenges
Society's responsibility	**Decreased socio-economic resilience**	Operational	Foster learning and innovation and conduct research to determine when and where to implement adaptive responses	3	Doing through 10-year audit period of FMP Conduct research (eg. Vulnerability Assessment) Part of what Mistik does annually – good at it shorter-term and will keep doing.
Society's responsibility	**Decreased socio-economic resilience**	Operational	Encourage societal adaptation (e.g. encourage changes in expectations)	3	Mistik doing in a small way. Policy and education can help.
Society's responsibility	**Decreased socio-economic resilience**	Operational	Make informed choices about preferred tree species composition for the future	2-3	Policy/Regulations challenges More research required

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Society's responsibility	**Decreased socio-economic resilience**	Operational	Conduct assessments in local communities to determine priorities and preferences	2-3	Very sensitive subject through time Human-value concepts (eg. As elders get older, lose influence and the youth providing different ideas, values, etc.).
Society's responsibility	**Decreased socio-economic resilience**	Operational	Strengthen local organizational and planning skills	2-3	Need more buy-in and support from the Province & Co-management process
Society's responsibility	**Decreased socio-economic resilience**	Operational	Compile local and community knowledge about past and current changes	2	
Society's responsibility	**Decreased socio-economic resilience**	Operational	Enhance dialogue amongst stakeholder groups to establish priorities for action on climate change adaptation in the forest sector	2-3	Mistik does this within and in surrounding areas of their FMA. Province needs to become more involved in this area and build trust and relationships in the North.
Society's responsibility	**Forest management plans and policies lack the flexibility that is required to respond to climate change**	Strategic	Evaluate the adequacy of existing environmental and biological monitoring networks for tracking the impacts of climate change on forest ecosystems, identify inadequacies and gaps in these networks and identify options to address them	4	Federal/Provincial initiative Long-term monitoring regionally/nationally needed Mistik doing on small scale on FMA and through research with the Vulnerability Assessment.
Society's responsibility	**Forest management plans and policies lack the flexibility that is required to respond to climate change**	Strategic	Practice adaptive management, which rigorously combines management, research, monitoring, and means of changing practices so that credible information is gained and management activities are modified by experience	2-3 that are within our mandate	As we know more, we will adapt; continue to improve; need more concrete evidence. Using low-risk, low-cost adaptations that are within our mandate.

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Society's responsibility	**Forest management plans and policies lack the flexibility that is required to respond to climate change**	Operational	Develop flexible forest management plans and policies that are capable of responding to climate change	2-plans (Mistik does) 4-policies (gov't.) – set by the government	
Society's responsibility	**Forest management plans and policies lack the flexibility that is required to respond to climate change**	Operational	Measure, monitor and report on indicators of climate change and sustainable forest management to determine the state of the forest and identify when critical thresholds are reached	1 (for SFM) 3	For climate change indicators (who defines critical thresholds and what are the indicators that they have been reached?)(could be vastly different depending on what you are managing for).
Society's responsibility	**Forest management plans and policies enhance the vulnerability of forests and forest-dependent communities to climate change**	Strategic	Development of forest management plans that reduce vulnerability of forest and forest dependent communities to climate change	2-3	Beyond our ability to ensure Mistik is only one small player here. Federal/Provincial initiative
Society's responsibility	**Forest management plans and policies enhance the vulnerability of forests and forest-dependent communities to climate change**	Strategic	Support knowledge exchange, technology transfer, capacity building and information sharing on climate change; maintain or improve capacity for communications and networking	3	Financial/Human resources challenges Province needs to be more involved. Mistik does internally and in a small way with the PAG.
Society's responsibility	**Forest management plans and policies enhance the vulnerability of forests and forest-dependent communities to climate change**	Strategic	Support research on climate change, climate impacts, and climate change adaptations; increase resources for basic climate change impacts and adaptation science	3	Mistik is doing to a degree Federal/Provincial initiative through research, policy, regulations, and education

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Society's responsibility	**Forest management plans and policies enhance the vulnerability of forests and forest-dependent communities to climate change**	Operational	Incorporate new knowledge about the future climate and forest vulnerability into forest management plans and policies	1	
Society's responsibility	**Forest management plans and policies enhance the vulnerability of forests and forest-dependent communities to climate change**	Operational	Involve the public in an assessment of forest management adaptation options	1-2	
Society's responsibility	**Forest management plans and policies enhance the vulnerability of forests and forest-dependent communities to climate change**	Operational	Gather information about natural and cultural heritage values and ensure that this knowledge is used as a part of the decision-making process established to manage for climate change impacts	2	
Society's responsibility	**Forest management policies and incentives do not encourage adaptation to climate change**	Strategic	Remove barriers and develop incentives to adapt to climate change	4	Doing this is some areas already, but cannot accomplish at all levels without other involvement from government and policy, etc.). Federal/Provincial initiative

(Adapted from CCFM Approach in Edwards et al., 2015).

APPENDIX C: LIST OF STAKEHOLDERS INVOLVED WITH MISTIK, REPRESENTED IN THE CASE STUDY

The following list includes stakeholders that are interested/involved with Mistik Management Ltd., in the FMA and surrounding area (Mistik, 2018):

- 8 existing advisory/co-management boards,
- Outfitters and trappers,
- Grazing permittees,
- Wild rice growers,
- Cabin owners,
- Snowmobile clubs
- Commercial fishing co-operatives,
- Small volume timber harvesters
- Meadow Lake Tribal Council,
- Meadow Lake Urban Municipality,
- Rural Municipality of Meadow Lake,
- 3rd Party Contractors.

APPENDIX D: RCP 8.5

In Phase Two of the CCFM approach, Mistik chose to base their assumptions regarding future warming on the projections of the IPCC Fifth Assessment Report. This projection was based on the scenario of warming called Representative Concentration Pathway (RCP). There are four pathways: RCP 8.5, RCP 6, RCP 4.5, and RCP 2.6 (IPCC 2007a). The core development team for the case study chose RCP 8.5. An RCP contains a set of starting values and the estimated emissions up to 2100, based on the assumptions about economic activity, energy sources, population growth and other socio-economic factors, along with historic and real-world information (IPCC 2007b). Each RCP contains the same categories of data, but the values vary greatly, reflecting different emission trajectories over time. RCP 8.5 is the "worst case" scenario out of the four, due to the rapid increase in emission concentrations and warming over three different time horizons. Under this scenario, if everything was to continue with the "business as usual" approach to carbon emissions, concentrations of CO_2 in the atmosphere would reach 950 ppm by 2100 (IPCC, 2014a). Temperatures increase by the end of the century significantly. The core team chose to base their climate change assumptions on this "worst case" scenario because they wanted to develop adaptation options that would be potentially applicable for extreme conditions and then they would be able to adapt them from there for less extreme conditions (Mistik, 2016).